ZOFNASS PROGRAM
FOR SUSTAINABLE INFRASTRUCTURE

The Lifecycle Sustainability Tool

INTEGRATING SUSTAINABILITY AND LCA

Prof. Dr. S.N. Pollalis
in collaboration with the National Research Council of Canada (NRCC)

February 2022

INTEGRATING SUSTAINABILITY AND LCA
PILOT APPLICATION ON TRANSPORTATION INFRASTRUCTURE PROJECTS

NATIONAL RESEARCH COUNCIL OF CANADA (NRCC)
PROF. DR. S.N. POLLALIS

22 OCTOBER 2020

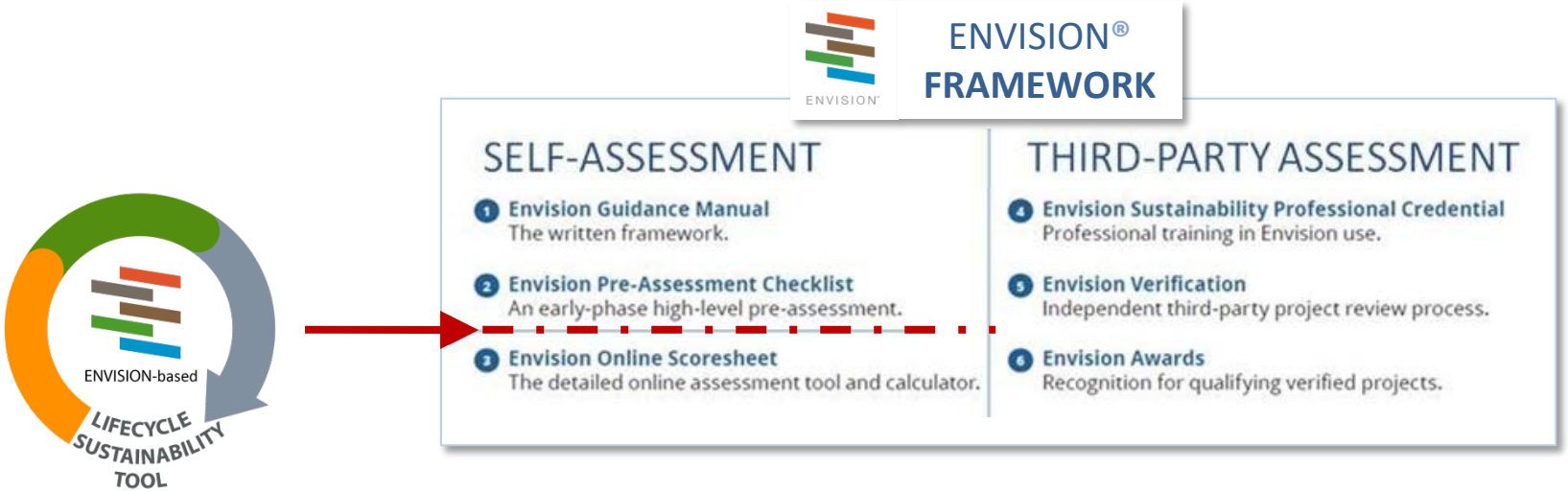
The Lifecycle Sustainability Tool

is an **Envision-based tool** that integrates sustainability assessment and lifecycle assessment (LCA) of infrastructure projects.

It is the outcome of the 2020 research conducted in collaboration with the National Research Center of Canada (NRCC) and with input from the Ontario Ministry of Transportation (MTO).

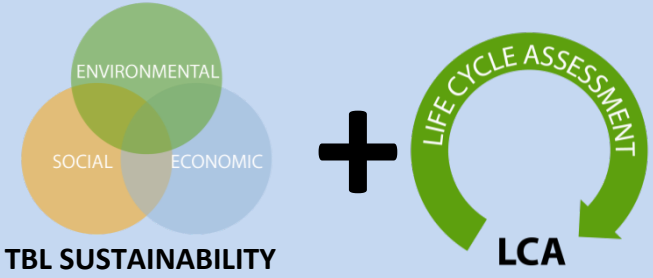
The Lifecycle Sustainability Tool

is suggested as **an additional tool for self-assessment within the Envision® framework to support early design and management decisions in projects.**



The research aimed to:

- explore the **relation between LCA and Triple bottom line** sustainability; and
- develop a new tool that **integrates sustainability assessment and lifecycle assessment for transportation infrastructure projects** to assist owners, consultants, and contractors in identifying and selecting among sustainable design and management alternatives **in early project development**



Within the tool project **sustainability is defined** as a balance of social, economic, and environmental trade-offs, considering the project's lifecycle performance and with emphasis on lowering the carbon footprint of projects

Key questions addressed through the research:

- What is the **relation between sustainability assessment tools and LCA** for infrastructure? (1) Is the full range of sustainability addressed by LCA?
(2) Do sustainability assessment tools adequately address lifecycle impacts?

- Project teams use both LCA and sustainability assessment tools for relevant projects. **Are both assessments needed**? **Could they be integrated in one tool?**

- The development of an integrated LCA-Triple bottom line Sustainability assessment tool, **should be based on the LCA methodology or rather the sustainability assessment methodology?**

1 LCA VS SUSTAINABILITY ASSESSMENT

LITERATURE REVIEW ON LCA

ISO LCA methodology in relation with TBL sustainability
&
Transportation Infrastructure specific LCA practice

ANALYSIS OF EXISTING SUSTAINABILITY ASSESSMENT TOOLS FOR INFRASTRUCTURE

In terms of:

- Life cycle perspective
- Triple Bottom line
- LCA methodology

ENVISION CEEQUAL delivered by bre ISCA

SELECTION OF ASSESSMENT FRAMEWORK

to be used as basis for developing the new tool

ENVISION

Used for

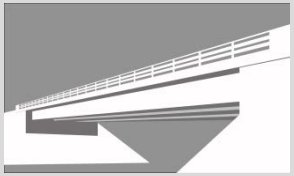
2 DEVELOPMENT OF THE LIFECYCLE SUSTAINABILITY TOOL

ENVISION-based LIFECYCLE SUSTAINABILITY TOOL

The tool was built upon the Envision tool using its structure of 5 impact categories & credits.

Applied & tested

3 PILOT APPLICATION OF THE TOOL ON A BRIDGE REPLACEMENT PROJECT



The tool was applied in a MTO's routine project – a bridge replacement project- to test if agency's areas of priority and concern are adequately captured.

LCA VS SUSTAINABILITY ASSESSMENT

The **common feature** of all the tools studied is the **Assessment of Impacts**

Both **LCA** and **Sustainability Assessment** assess **'IMPACTS'**

- **'Impact'** refers to the **effect** a project has on the **environment, on the society and the economy.** Impacts can be positive or negative, short-term or long-term, intended or unintended, actual or potential.

- **Impact** (positive or negative) represents a **project's contribution to the sustainable development**.

Lifecycle Assessment

Assesses **one (or more) specific impacts** depending on the type of LCA:

E- LCA (ENVIRONMENTAL LCA) assesses → **Environmental impact**

LCC (LIFE CYCLE COSTING) assesses → **Economic impact**

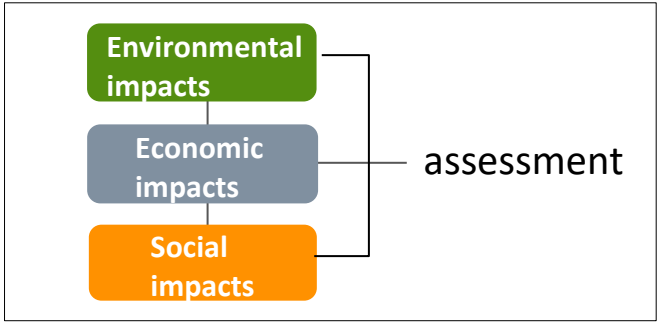
S-LCA (SOCIAL LCA) assesses → **Social impact**

LC assessment is more detailed, but its comprehensiveness in terms of lifecycle stages **depends on the boundary set**

VS

Sustainability Assessment

Assesses a wider range **of pre-defined TBL** impacts:



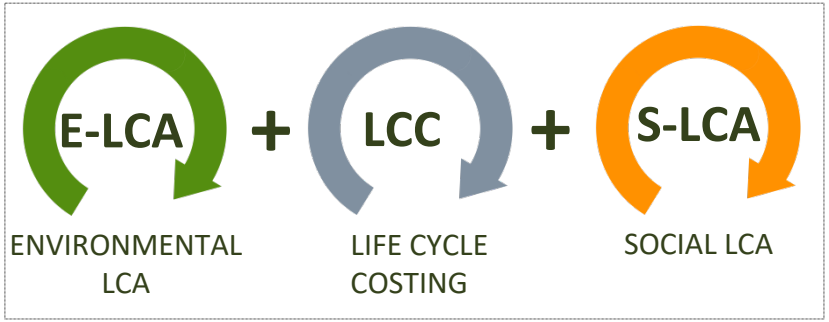
However, its comprehensiveness in terms of lifecycle stages depends on the tool and is **less detailed than an LCA**.

Moreover, **tools request independent LCA assessments to complete ratings** for certain impacts, such as carbon, energy etc.

Regarding the development of an integrated LCA – TBL Sustainability Assessment Tool

Lifecycle Assessment Methodology

According to the LCA methodology, a comprehensive Sustainability Lifecycle assessment is defined as **the conceptual 'equation':**

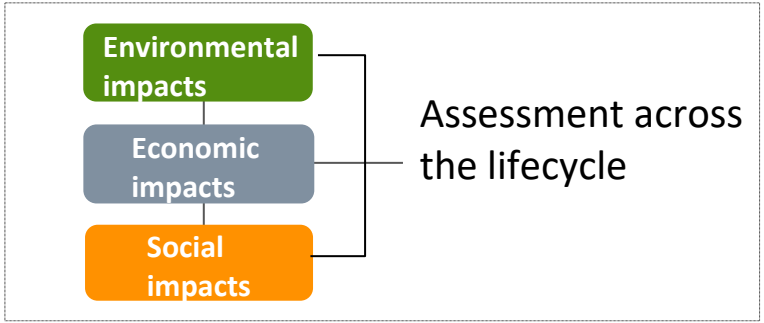


This would represent triple effort, performing 3 times a complex, highly technical, **labor- and data-intensive process**

VS

Sustainability Assessment Methodology

In the case of Sustainability Assessment tools, by default, a more comprehensive TBL sustainability assessment is performed.



Enhancements would be required in lifecycle considerations to ensure comprehensiveness.

A Sustainability Assessment tool, **Envision**, is selected to be used as the basis for the development of the new integrated tool

Why a Sustainability Framework as a basis for the new Tool development:

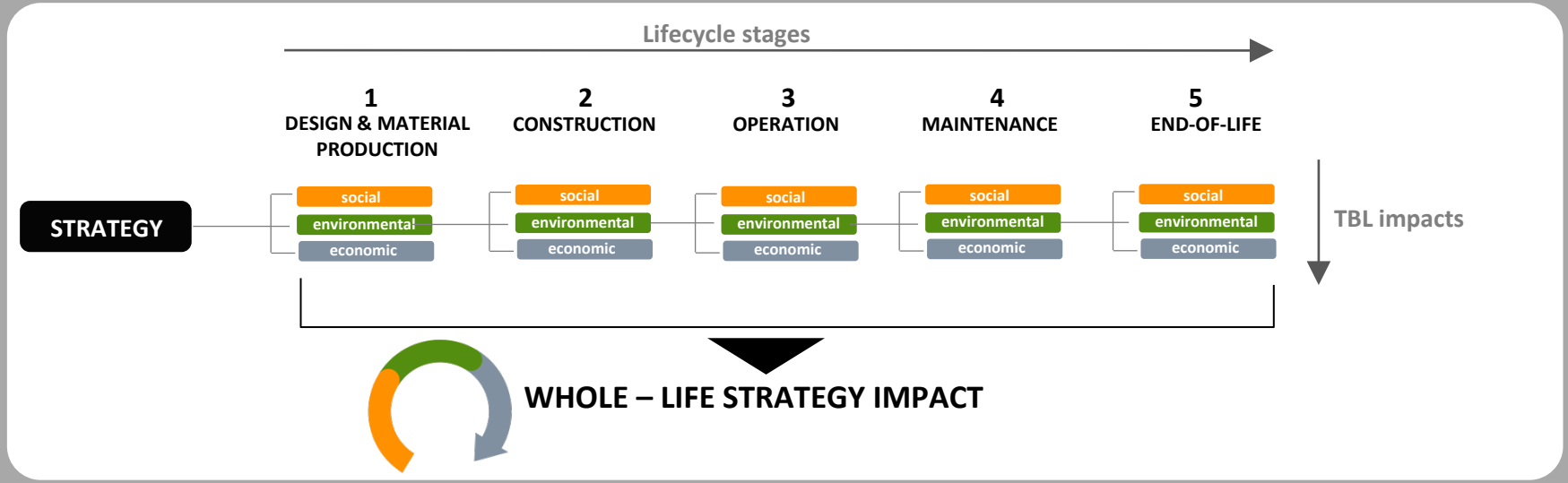
- A sustainability framework, by definition, accounts for the environmental, social, and economic impacts of a project.
- The sustainability frameworks consider the entire lifecycle of a project.
- The sustainability frameworks propose a shift of focus from monetary to the total value.
- A straight-forward, easy-to-use model is required.

Moreover, in relation to transportation in infrastructure projects:

- The sustainability rating systems sufficiently capture the nature of sustainable transportation strategies and the areas of priority and concern, such as:
  - selection between replacement or major rehabilitation
  - Durability and reduction of maintenance needs
  - Impacts of construction to the community (disruption of access)
  - Materials
  - Costs and cost offsetting

Additional consideration for the new integrated tool

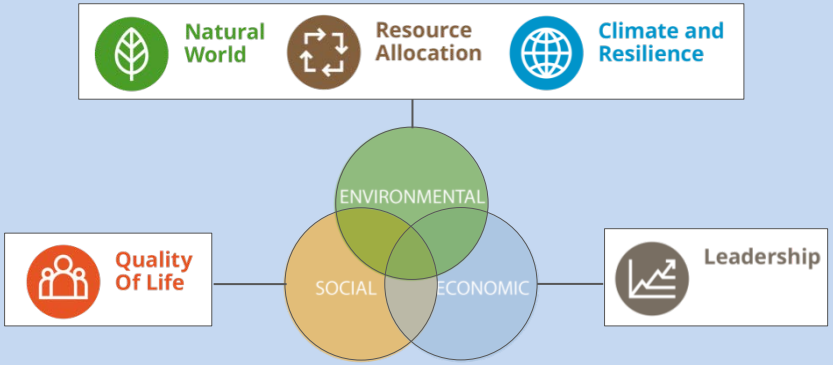
During **early decision making**, project teams would best benefit from a tool that allows them to understand the **whole-life impacts associated with each strategy** they consider incorporating into a project



DEVELOPMENT OF THE TOOL

Impact assessment in Envision

Envision structures TBL impacts into 5 broad **Impact Categories**:



Credits assess specific impacts that fall under these broad categories

e.g. Resource Allocation

RA1.1	Support Sustainable Procurement Practices
RA1.2	Use Recycled Materials
RA1.3	Reduce Operational Waste
RA1.4	Reduce Construction Waste
RA1.5	Balance Earthwork On Site
RA2.1	Reduce Operational Energy Consumption
RA2.2	Reduce Construction Energy Consumption
RA2.3	Use Renewable Energy
RA2.4	Commission & Monitor Energy Systems
RA3.1	Preserve Water Resources
RA3.2	Reduce Operational Water Consumption
RA3.3	Reduce Construction Water Consumption
RA3.4	Monitor Water Systems

→ **Impact assessed:** use of primary resources

ENVISION STRUCTURE UNITS

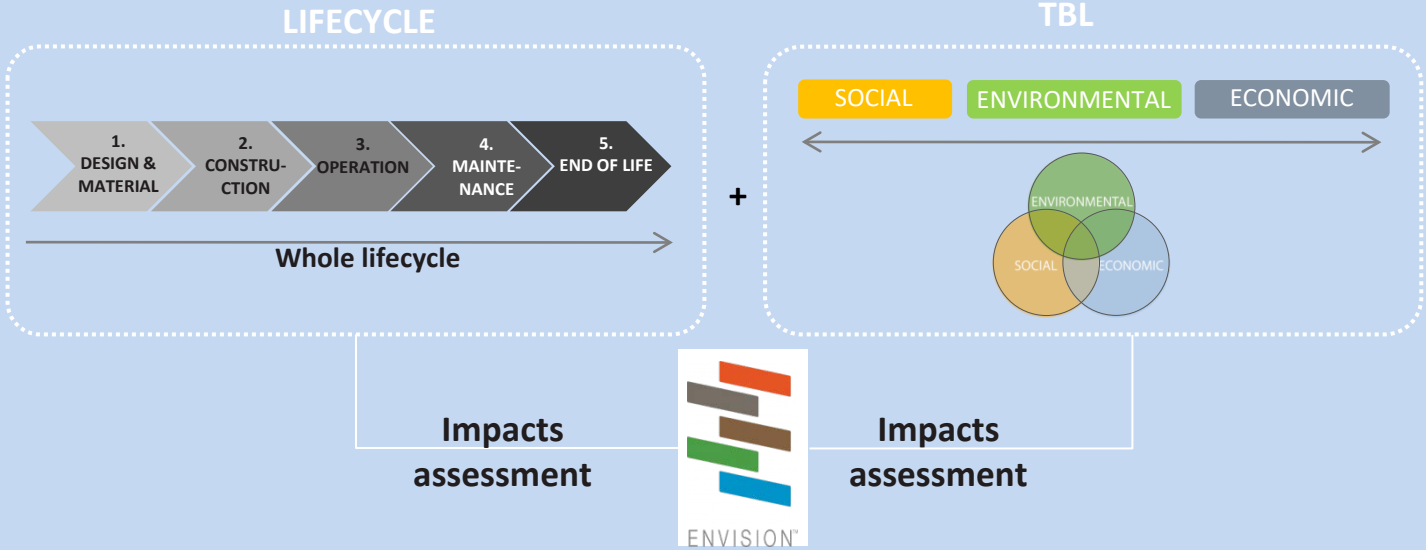
IMPACT CATEGORY → SUBCATEGORY → CREDIT

THE NEW TOOL

uses the **Envision structure** of Impact Categories, Subcategories & Credits

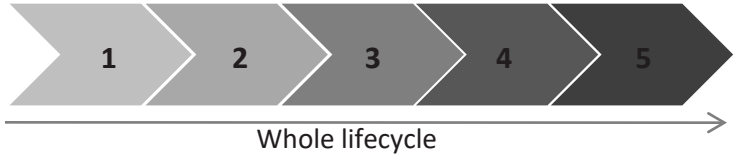
Based on the Envision Framework, the proposed tool **assesses impacts:**

- **Across the lifecycle** of infrastructure projects
- With respect to **all areas of the TBL categories**



TBL IMPACTS & LC STAGES are the key components of the new tool

LIFECYCLE STAGES CONSIDERED IN THE TOOL



1. DESIGN & MATERIAL PRODUCTION
2. CONSTRUCTION
3. OPERATION
4. MAINTENANCE (minor and/or major rehabilitation)
5. END OF LIFE

LC STAGES

The lifecycle stages of infrastructure projects are defined based on the literature review and the needs of infrastructure projects

TBL IMPACTS ASSESSED BY THE TOOL

SOCIAL	ENVIRONMENTAL	ECONOMIC	
		AGENCY	USER
Access	Materials	Capital	Travel time
Safety	Energy	(initial)cost	value
Health	Embodied energy	O&M cost	Vehicle cost
Noise	Water	Rehabilitation	Fuel cost
Light pollution	Water quality	cost	Fare cost
Community	Embodied water	Replacement cost	Accident cost
satisfaction	Air quality	Residual value	Health cost
Inclusivity	Waste	Revenues	Job creation
Equity	Soil quality	Delay cost	Economic
Sense of place	Emissions	Liability claim /	prosperity
Wellbeing	Embodied carbon	Penalty cost	Resilience
Livability	Ecosystem quality	Noise cost	value
Integration	Resource depletion	Restoration cost	Ecosystem
Capacity building	Land occupation	Resilience value	services
Social resilience	Climate change	Ecosystem	value
	Ecological Resilience	services value	

TBL IMPACTS

- A targeted interpretation of the Envision manual reveals a list of specific **TBL impacts that are extensively addressed by the tool**
- Impacts are a **key component** of the tool
- The areas of impact are primarily **classified based on the TBL category** they fall into

The list of impacts includes only the **abbreviations of the impacts** addressed.

The exact definitions for each one of the impacted areas are included in the new tool's manual.

Examples of definitions

Materials= use of primary materials

Energy= fuel & electricity use; depending on the credit could refer to fuel use of equipment/ vehicles.

Water = quantity of freshwater used during construction works and O&M, as well as embodied water of materials

Resiliency value= value of protection from the effects of future/repeat disasters or enhanced reliability, such as avoided future cost of damage, displacement, or cost of loss of service that may create a financial downturn or slowdown for the organization.

Travel time value= avoided cost of time spent on transport. It includes costs to businesses when their employees and vehicles spend on travel and costs to consumers of personal (unpaid) time spent on travel.

TBL IMPACTS ASSESSED BY THE TOOL

SOCIAL	ENVIRONMENTAL	ECONOMIC	
		AGENCY	**USER**
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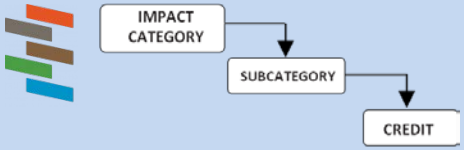
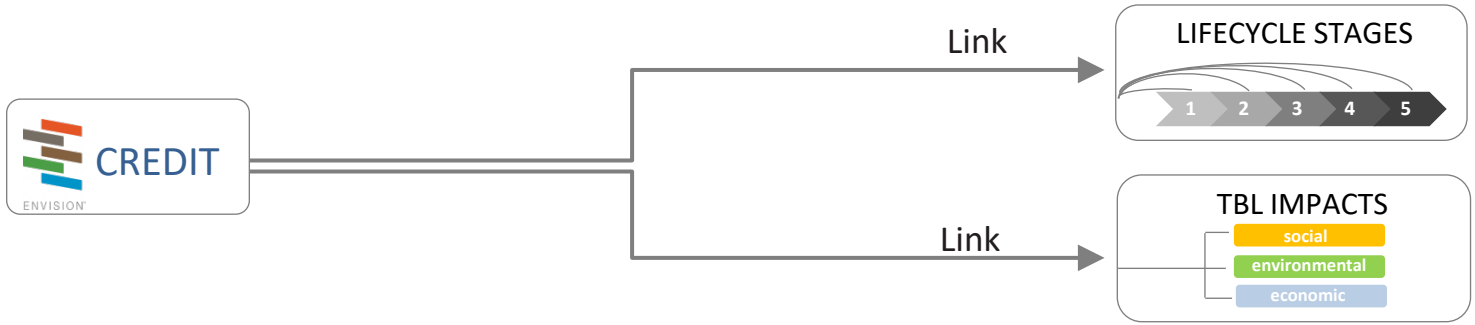
	Ecological Resilience	services value	

How is the **Envision Framework** used to integrate **TBL-impacts assessment** with **LCA assessment?**

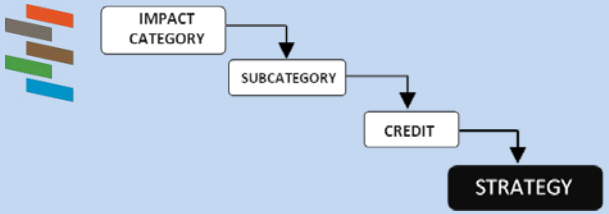


By linking its fundamental **structural unit – the CREDIT**– with **LC STAGES** and **TBL-IMPACTS**

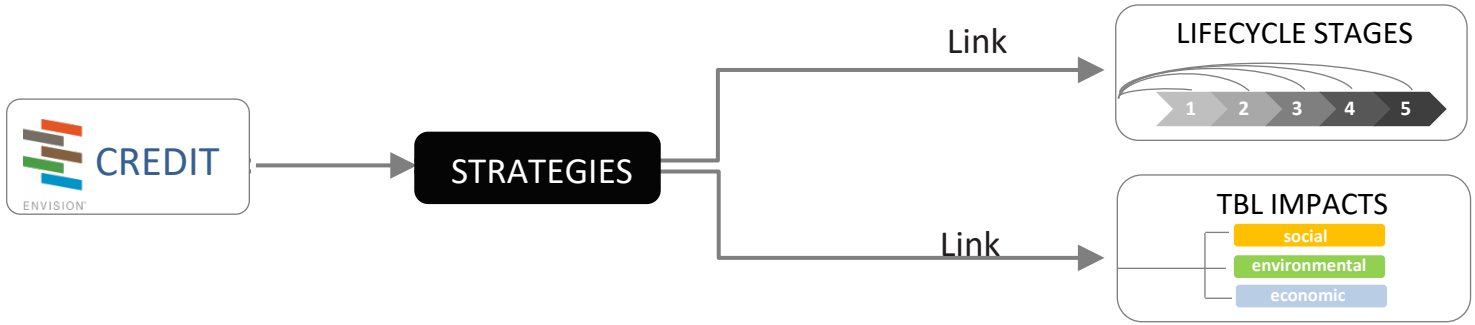


However, **for most credits this linking is not direct,** as there are various approaches to address a credit with different outcomes each.

To achieve the link between **CREDITS**, **LC STAGES** and **TBL IMPACTS, the tool introduces an additional 'unit': STRATEGIES**



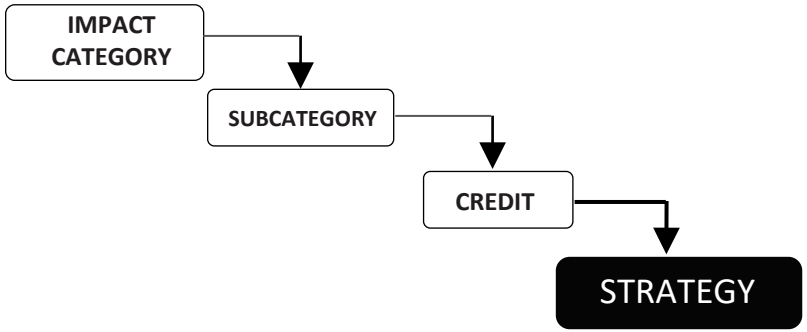
Strategies are **the connecting link** between each **credit** with the **lifecycle stages** and the **TBL impacts**



Each Envision credit is **linked with one or more complementary or alternative strategies**, which in turn result in several impacts (linked TBL-impacts) across the lifecycle stages (linked LC stages) of the project

The new tool uses **strategies as a new structure unit** within the Envision structure

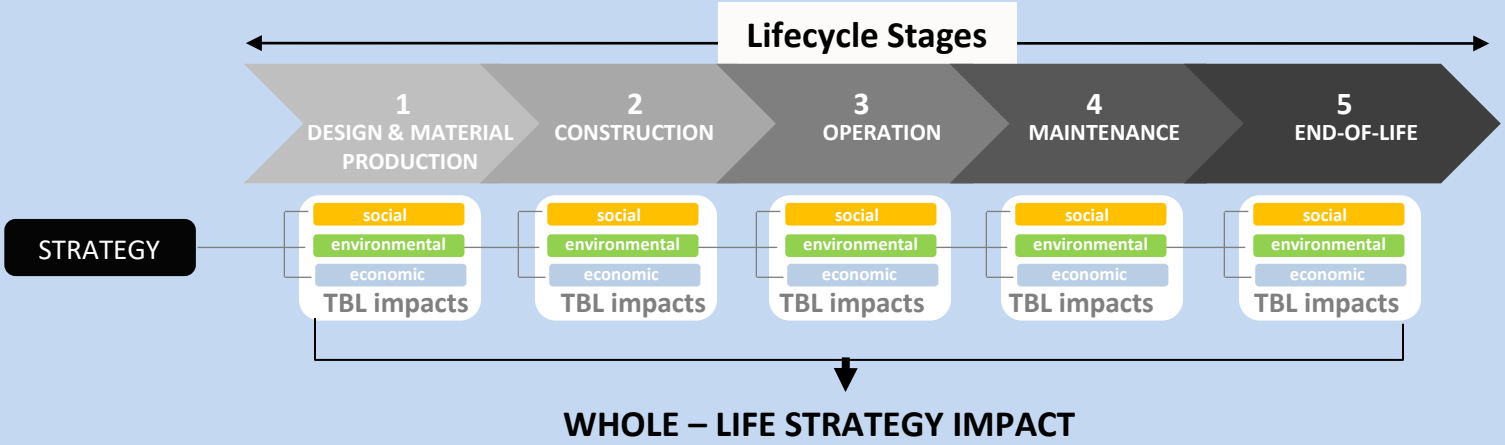
ENVISION STRUCTURE UNITS



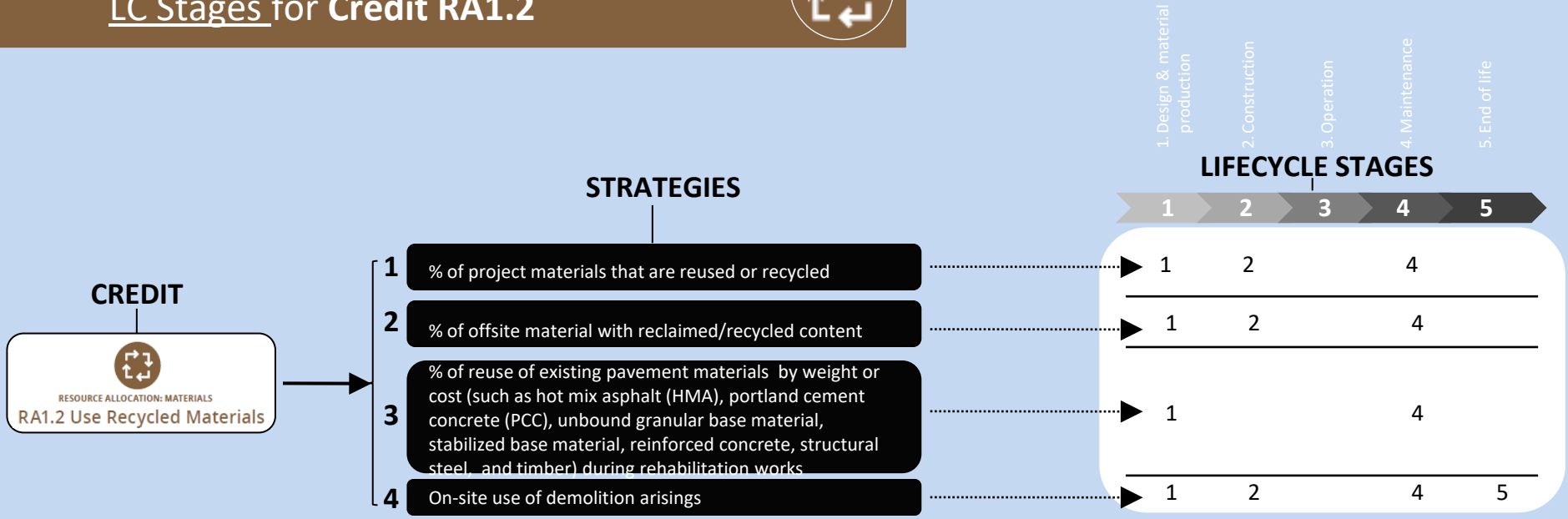
- Strategies are **extracted from the Envision manual.** They are found in the description of each credit's evaluation criteria.
- In Envision **they appear as "performance indicators",** guiding towards the achievement of the respective credits.

THE LIFECYCLE DIMENSION OF IMPACTS

- Apart from connecting credits with lifecycle stages and TBL impacts, **the strategies also link TBL – impacts with LC stages**
- In this sense, the TBL impacts assigned for each strategy take into consideration the whole lifecycle of the strategy

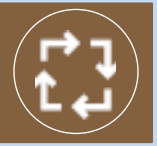


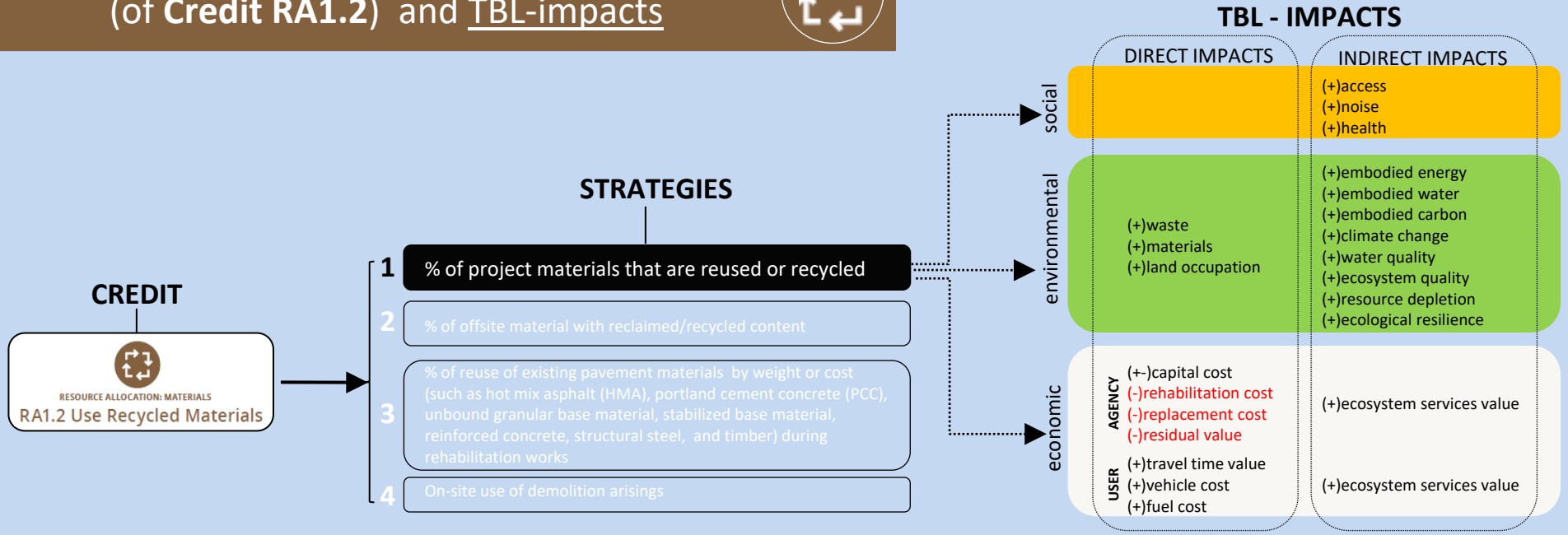
Example of linked Strategies and LC Stages for **Credit RA1.2**



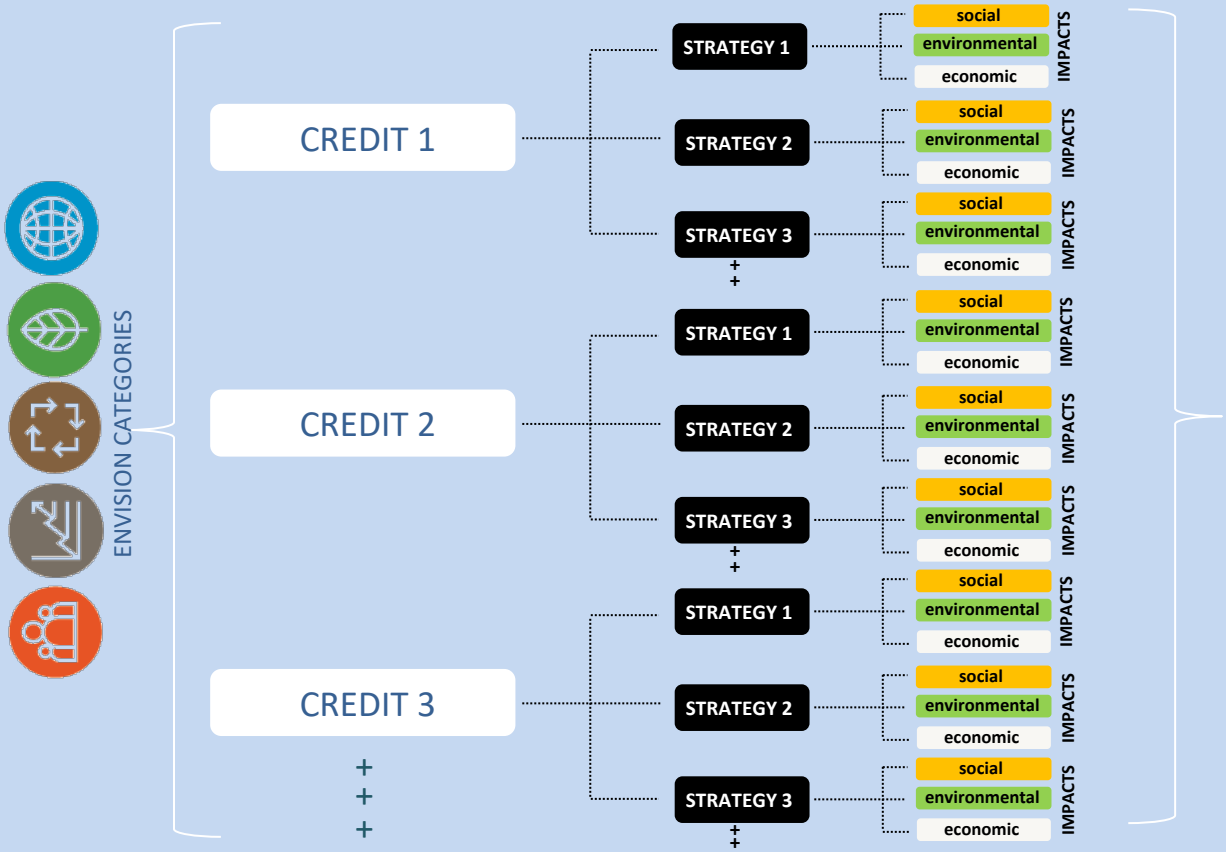
CREDIT → STRATEGIES → TBL IMPACTS (social, environmental, economic)

Example of links between one Strategy (of **Credit RA1.2**) and TBL-impacts





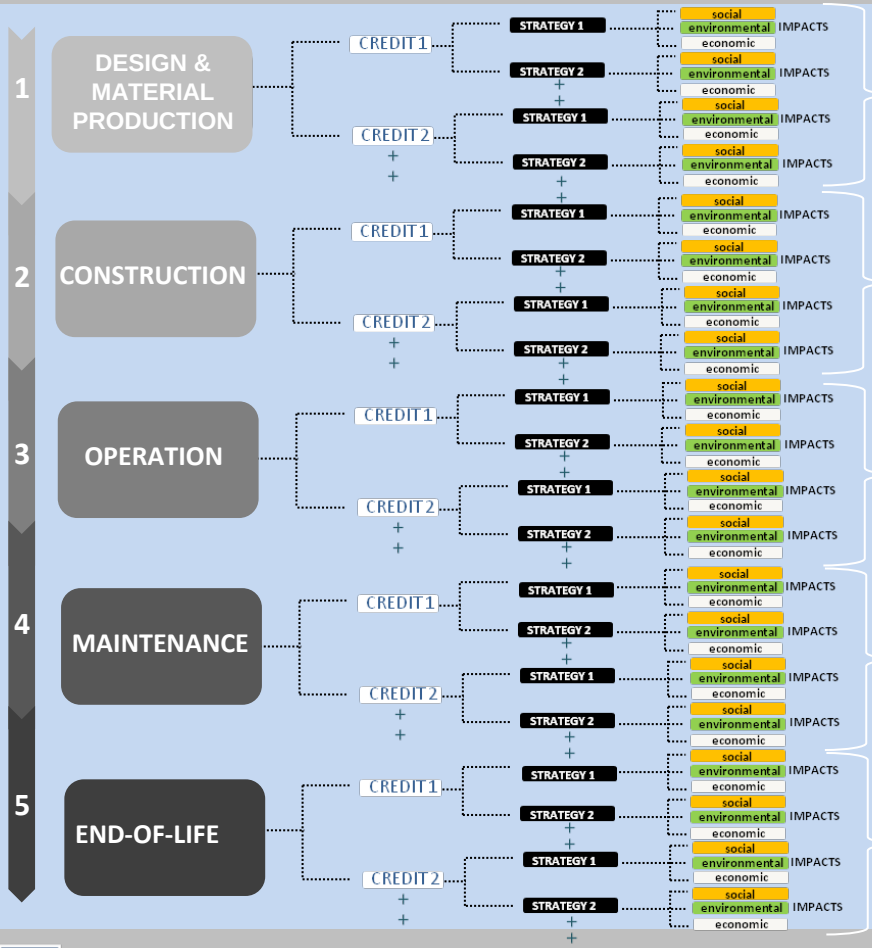
TOOL STRUCTURE



All Envision credits **from all Envision categories** are **linked through their strategies to TBL impacts**

Based on Envision's structure, the tool's structure is formed through the links described

TOWARDS WHOLE LIFE PROJECT IMPACTS



DESIGN & MATERIAL PRODUCTION IMPACTS

CONSTRUCTION IMPACTS

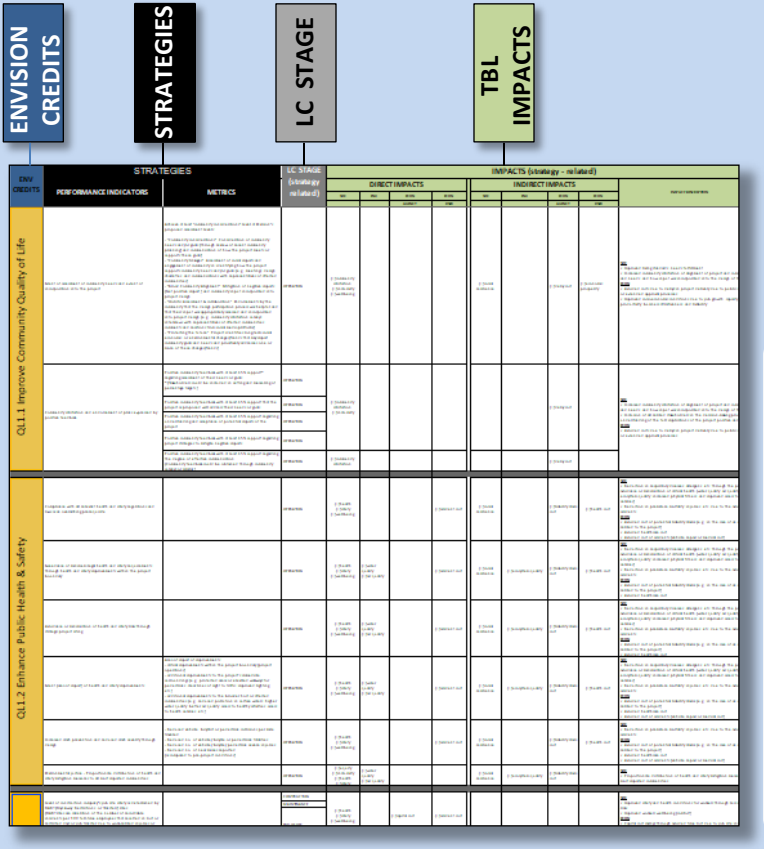
OPERATION IMPACTS (O&M)

MAINTENANCE IMPACTS (major or minor rehabilitation)

END-OF-LIFE IMPACTS (replacement or deconstruction)

WHOLE LIFE PROJECT IMPACTS

The tool identifies and classifies all TBL impacts from all LC stages



BACKGROUND EXCEL TABLE

The connections **between ENV Credits, LC stages, Strategies** and **TBL Impacts** are mapped in an extensive background excel table, which will provide the basis for the tool's function.

Additional information is inserted to allow **for multilevel analysis on several parameters:**

- Strategies are accompanied by **their qualitative and quantitative requirements (metrics**)
- **All impact areas** are listed for each strategy
- **Each impact is accompanied by properties** as to the type of its connection with the strategy: (Direct or indirect, environmental, social, economic, economic impact to user, economic impact to agency)

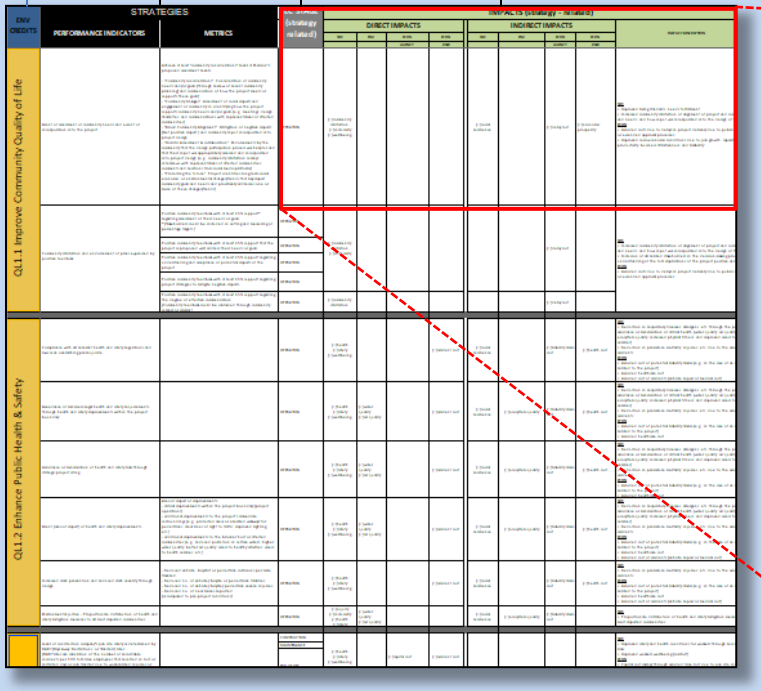
BACKGROUND EXCEL TABLE

ENVISION CREDITS

STRATEGIES

LC STAGE

TBL IMPACTS



BACKGROUND EXCEL TABLE

Zooming in

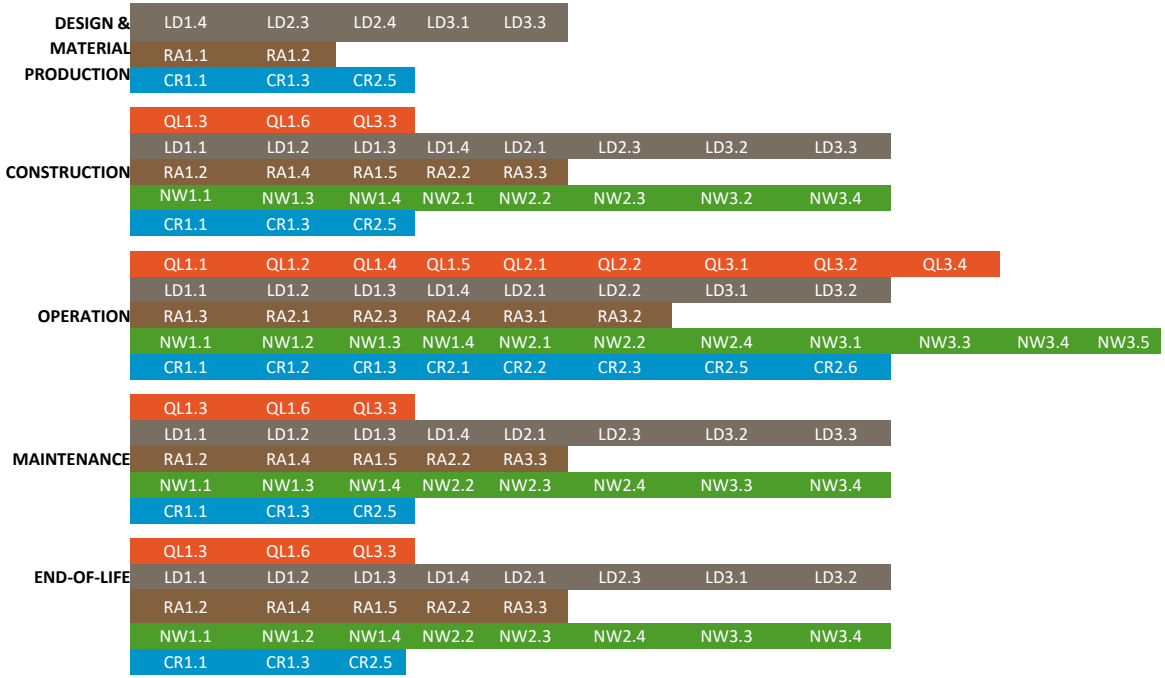
LC STAGE)	IMPACTS								IMPACT DESCRIPTION
	DIRECT IMPACTS				INDIRECT IMPACTS				
	SOC	ENV	ECON		SOC	ENV	ECON		
			AGENCY	USER			AGENCY	USER	
OPERATION	(+)community satisfaction (+)inclusivity (+)wellbeing				(+)social resilience		(+)delay cost	(+)economic prosperity	**SOC** • Improved living standards, needs fulfilment • Increased community satisfaction of alignment of project and community goals and needs; and how input was incorporated into the design of the project **ECON** • Avoided costs due to delays in project delivery due to public opposition, or extended approval processes • Improved socioeconomic conditions due to job growth, capacity building, productivity, business attractiveness, and livability

The extract shows the included information regarding the impacts of a strategy

CREDITS GROUPINGS

The background excel table allows for several new interpretations of the Envision credits based on the additional attributes inserted (strategies, impacts and lifecycle stages)
Indicatively, credits **can be grouped under the Lifecycle stages** they address **or under the TBL categories** they have impacts on

LIFECYCLE STAGES GROUPING



CREDITS GROUPINGS

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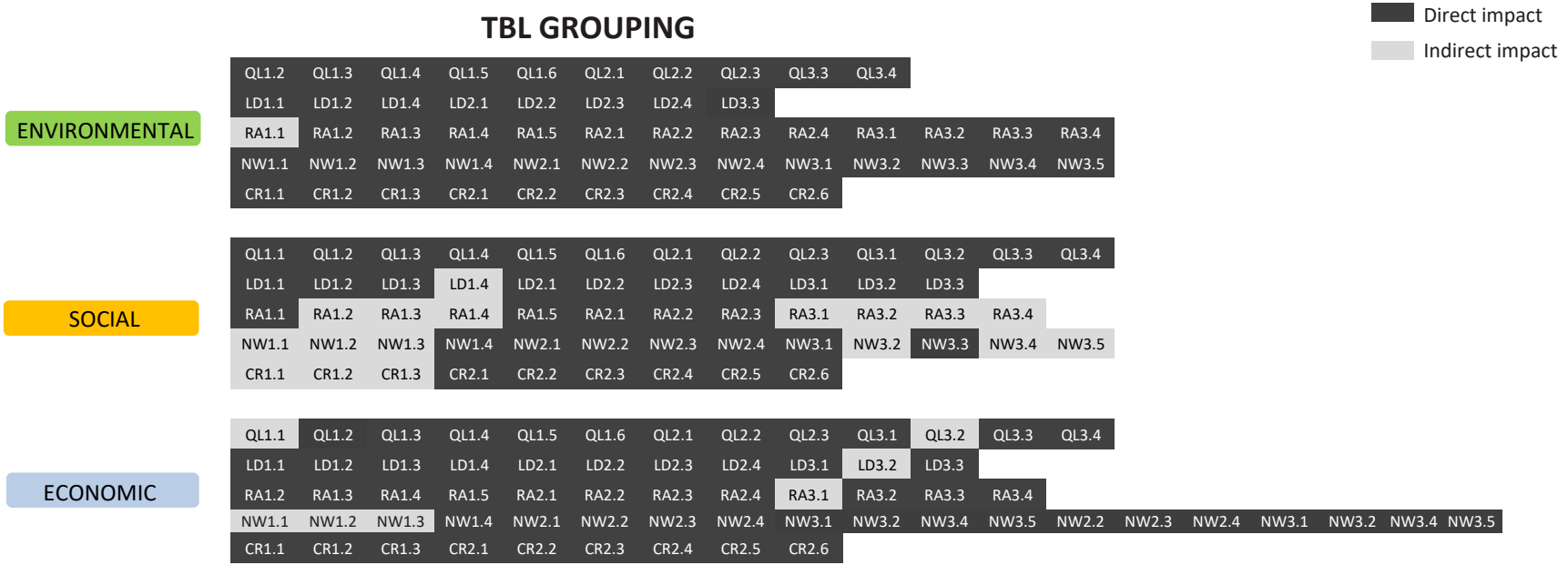


The information inserted in the background excel table also revealed a set of 6 credits with special characteristics:

the KEY CREDITS.

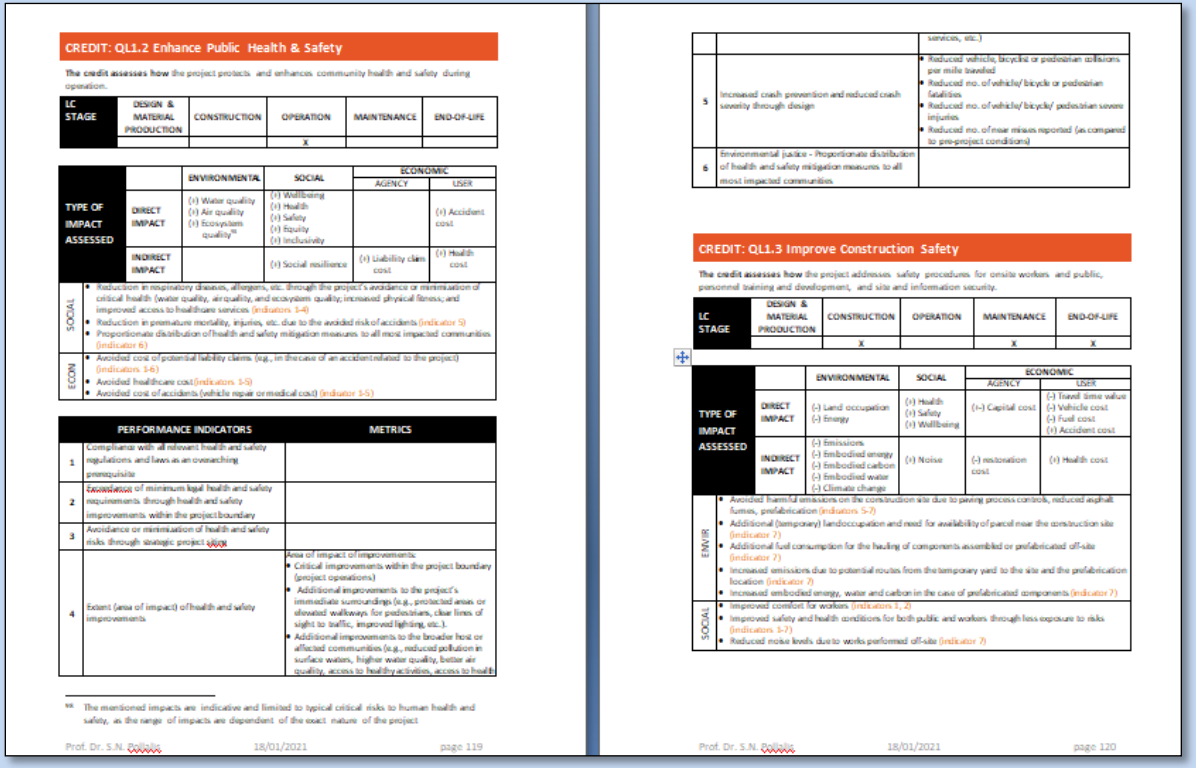
- The main characteristic of key credits is that their achievement is the result of a set of strategies that appear in other Envision credits. **They require thus input from other credits' strategies**
- Another particular feature is that they **explicitly refer to core impacts**, which are at the centre of the research and aim to provide a basis for their quantification:

LD1.3 Provide For Stakeholder Engagement
LD3.1 Stimulate Economic Prosperity
LD3.3 Conduct A Lifecycle Economic Evaluation
CR1.1 Reduce net embodied carbon
CR2.2 Reduce GHG Emissions
CR2.5 Maximize Resilience

CORE IMPACTS ADDRESSED

- Impact on the community
- Impact on cost
- Impact on climate change
- Impact on resilience against future uncertainty

Typical layout of credit's description in LC tool's manual



CREDIT: QL1.2 Enhance Public Health & Safety

The credit assesses how the project protects and enhances community health and safety during operation.

LC STAGE	DESIGN & MATERIAL PRODUCTION	CONSTRUCTION	OPERATION	MAINTENANCE	END-OF-LIFE
			X		

TYPE OF IMPACT ASSESSED		ENVIRONMENTAL	SOCIAL	ECONOMIC	
				AGENCY	USER
	DIRECT IMPACT	(+) Water quality (+) Air quality (+) Ecosystem quality[ss]	(+) Wellbeing (+) Health (+) Safety (+) Equity (+) Inclusivity		(+) Accident cost
	INDIRECT IMPACT		(+) Social resilience	(+) Liability claim cost	(+) Health cost
SOCIAL	• Reduction in respiratory diseases, allergens, etc. through the project's avoidance or minimization of critical health (water quality, air quality, and ecosystem quality; increased physical fitness; and improved access to healthcare services (indicators 1-4) • Reduction in premature mortality, injuries, etc. due to the avoided risk of accidents (indicator 5) • Proportionate distribution of health and safety mitigation measures to all most impacted communities (indicator 6)				
ECON	• Avoided cost of potential liability claims (eg., in the case of an accident related to the project) (indicators 1-6) • Avoided healthcare cost (indicators 1-5) • Avoided cost of accidents (vehicle repair or medical cost) (indicator 1-5)				

	PERFORMANCE INDICATORS	METRICS
1	Compliance with all relevant health and safety regulations and laws as an overarching prerequisite	
2	Exceedance of minimum legal health and safety requirements through health and safety improvements within the project boundary	
3	Avoidance or minimization of health and safety risks through strategic project work	
4	Extent (area of impact) of health and safety improvements	Area of impact of improvements: • Critical improvements within the project boundary (project operations) • Additional improvements to the project's immediate surroundings (e.g., protected areas or elevated walkways for pedestrians, clear lines of sight to traffic, improved lighting, etc.). • Additional improvements to the broader host or affected communities (e.g., reduced pollution in surface waters, higher water quality, better air quality, access to healthy activities, access to health

[ss] The mentioned impacts are indicative and limited to typical critical risks to human health and safety, as the range of impacts are dependent of the exact nature of the project

Prof. Dr. S.N. Pollalis 18/01/2021 page 119

		services, etc.)
5	Increased crash prevention and reduced crash severity through design	• Reduced vehicle, bicyclist or pedestrian collisions per mile traveled • Reduced no. of vehicle/ bicycle or pedestrian fatalities • Reduced no. of vehicle/ bicycle/ pedestrian severe injuries • Reduced no. of near misses reported (as compared to pre-project conditions)
6	Environmental justice - Proportionate distribution of health and safety mitigation measures to all most impacted communities	

CREDIT: QL1.3 Improve Construction Safety

The credit assesses how the project addresses safety procedures for onsite workers and public, personnel training and development, and site and information security.

LC STAGE	DESIGN & MATERIAL PRODUCTION	CONSTRUCTION	OPERATION	MAINTENANCE	END-OF-LIFE
		X		X	X

TYPE OF IMPACT ASSESSED		ENVIRONMENTAL	SOCIAL	ECONOMIC	
				AGENCY	USER
	DIRECT IMPACT	(-) Land occupation (-) Energy	(+) Health (+) Safety (+) Wellbeing	(+-) Capital cost	(-) Travel time value (-) Vehicle cost (-) Fuel cost (+) Accident cost
	INDIRECT IMPACT	(-) Emissions (-) Embodied energy (-) Embodied carbon (-) Embodied water (-) Climate change	(+) Noise	(-) restoration cost	(+) Health cost
ENVIR	• Avoided harmful emissions on the construction site due to paving process controls, reduced asphalt fumes, prefabrication (indicators 5-7) • Additional (temporary) landoccupation and need for availability of parcel near the construction site (indicator 7) • Additional fuel consumption for the hauling of components assembled or prefabricated off-site (indicator 7) • Increased emissions due to potential routes from the temporary yard to the site and the prefabrication location (indicator 7) • Increased embodied energy, water and carbon in the case of prefabricated components (indicator 7)				
SOCIAL	• Improved comfort for workers (indicators 1, 2) • Improved safety and health conditions for both public and workers through less exposure to risks (indicators 5-7) • Reduced noise levels due to works performed off-site (indicator 7)				

Prof. Dr. S.N. Pollalis 18/01/2021 page 120

INTEGRATING SUSTAINABILITY AND LCA
PILOT APPLICATION ON TRANSPORTATION INFRASTRUCTURE PROJECTS

NATIONAL RESEARCH COUNCIL OF CANADA (NRCC)
PROF. DR. S.N. POLLALIS

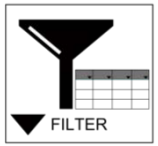
22 OCTOBER 2020

FUNCTION AND USE OF THE TOOL

- The **LC tool mapped the Envision structure** and content in a computer model in excel format
- Through a new coding applied in the background excel table, the attributes assigned to each strategy -and indirectly to each credit- allow the user to **perform analyses that focus in Lifecycle stages and Triple Bottom Line (TBL) impacts.**
- Therefore, the **enhanced** Envision manual was **transformed into a searchable and filterable format**, enabling and facilitating targeted analyses.

The most effective and useful capability of the tool is that it can **automatically identify and extract all the Envision credits** that relate to **one or more selected impacts.**

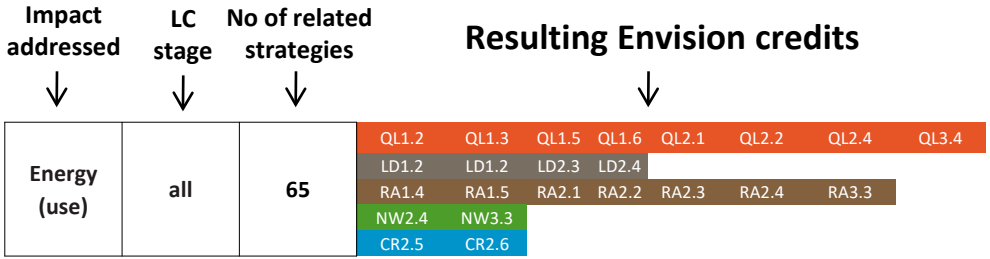
How can the tool identify credits based on selected criteria (e.g. specific TBL impacts or LC stages)?



By applying Excel's Autofilter feature to narrow data. All Envision credits can be thus filtered based on the criteria that the user selects (e.g. one or more TBL impacts or LC stages).

Example of use :

FILTERING CREDITS BASED ON **ONE SELECTED TBL-IMPACT**

OBJECTIVE	The project team is interested in assessing the **energy consumption** throughout the whole lifecycle of a project	
FILTER USED	**Impacts: 'energy'** **LC stage: -**	Envision credits are filtered based on the impact '**energy**' during all LC stages
FILTER RESULT		

Example of use :

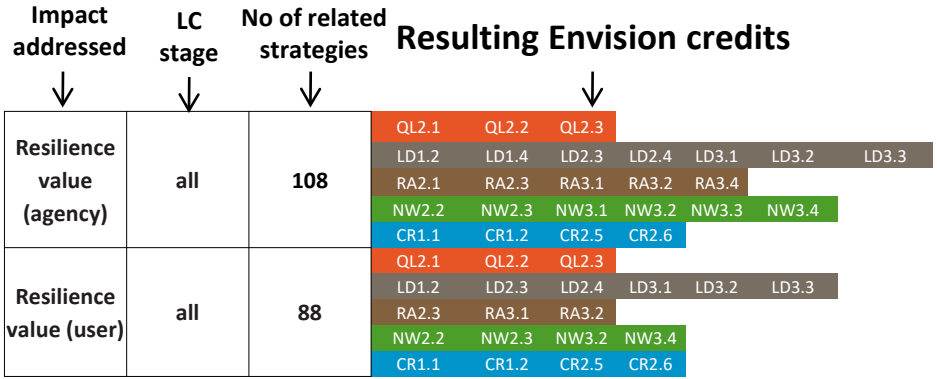
FILTERING CREDITS BASED ON **ONE SELECTED TBL-IMPACT DURING A SPECIFIC LC STAGE**

OBJECTIVE	The project team is interested in assessing the **energy consumption** during **construction**	
FILTER USED	**Impacts: 'energy'** **LC stage: 'construction'**	Envision credits are filtered based on the impact '**energy**' only during the **construction phase** (on site)
FILTER RESULT		

Impact addressed	LC stage	No of related strategies	Resulting Envision credits
Energy (use)	Construction	21	QL1.3, QL1.6, LD1.2, LD2.3, RA1.2, RA2.2

Example of use :

FILTERING CREDITS BASED ON **MULTIPLE TBL-IMPACTS**

OBJECTIVE	The project team is interested **in assessing project resilience to climate change**	
FILTER USED	**Impacts:** **'resilience value (agency)'** **'resilience value (user)'** **LC stage:** -	Envision credits are filtered based on the impacts related to **resilience** during all LC stages
FILTER RESULT		

As shown by the filter result the tool assist to identify resilience-related credits beyond the Climate & Resilience category.

FILTERING **FOR THE ACHIEVEMENT OF KEY CREDITS**

- The tool **has identified specific TBL core impacts** that each key credit needs to address
- The tool **identifies all strategies** across various credits **that contribute to these impacts by filtering all credits based on** each key credit's **core impact**

KEY CREDITS	CORE IMPACTS ADDRESSED	
	IMPACT FOR FILTERING	TBL CATEGORY
LD1.3 Provide For Stakeholder Engagement	community satisfaction	SOCIAL
LD3.1 Stimulate Economic Prosperity	economic prosperity	ECONOMIC
	travel time value	ECONOMIC
LD3.3 Conduct A Lifecycle Economic Evaluation	all economic impacts	ECONOMIC
CR1.1 Reduce net embodied carbon	embodied carbon	ENVIRONMENTAL
CR2.2 Reduce GHG Emissions	emissions	ENVIRONMENTAL
CR2.5 Maximize Resilience	resilience value	ECONOMIC

Example of use :

FILTERING **FOR THE ACHIEVEMENT OF KEY CREDITS**

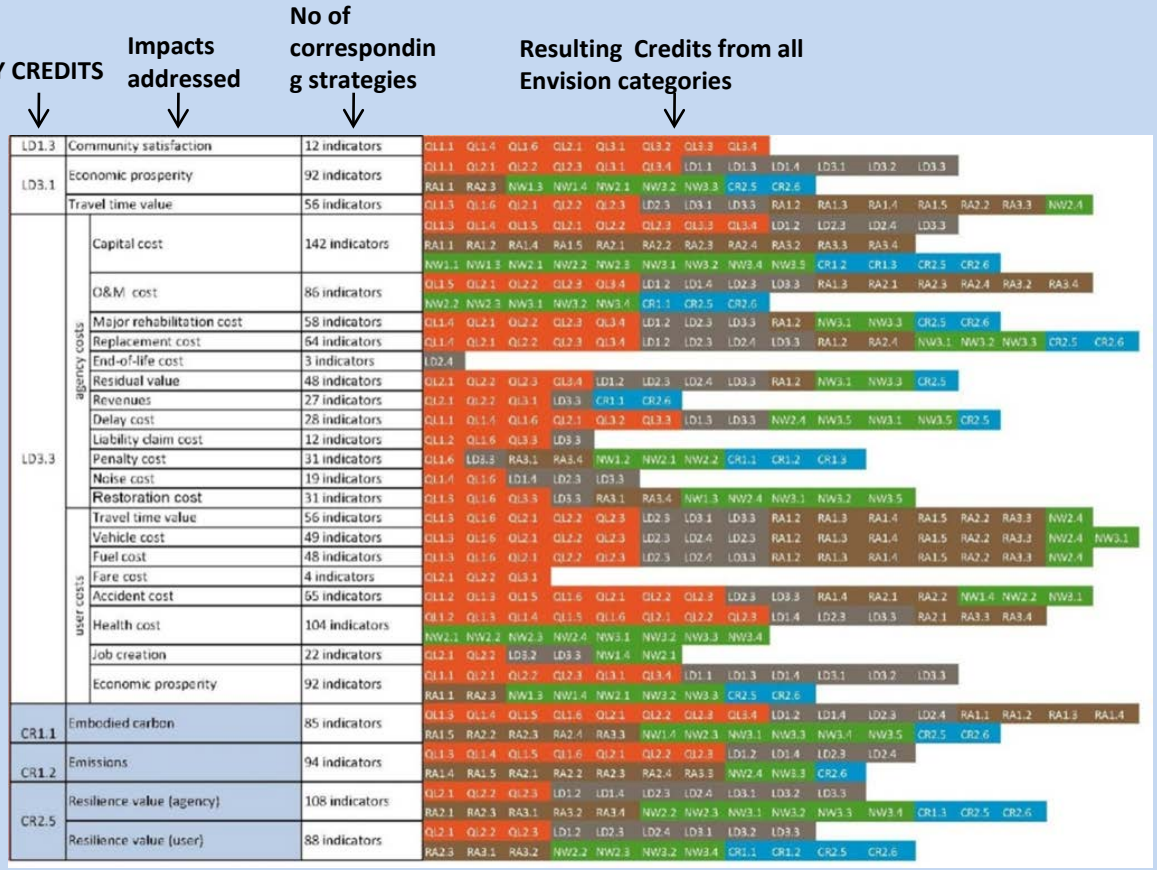
OBJECTIVE	The project team is interested in **achieving Key Credit LD3.1 Stimulate Economic Prosperity**	
FILTER USED	**Impacts:** **'economic prosperity'** **'travel time value'** **LC stage:** **-**	Envision credits are filtered based on the **core impacts addressed** by the Key Credit

FILTER RESULT

Impact addressed	LC stage	No of related strategies	Resulting Envision credits
Economic prosperity	all	92	QL1.1 QL2.1 QL2.2 QL2.3 QL3.1 QL3.4 LD1.1 LD1.3 LD1.4 LD3.1 LD3.2 LD3.3 RA1.1 RA2.3 NW1.3 NW1.4 NW2.1 NW3.2 NW3.3 CR2.5 CR2.6
Travel time value	all	56	QL1.3 QL1.6 QL2.1 QL2.2 QL2.3 LD2.3 LD3.1 LD3.3 RA1.2 RA1.3 RA1.4 RA1.5 RA2.2 RA2.3 NW2.4

Travel time value= avoided cost of time spent on transport. It includes costs to businesses when their employees and vehicles spend on travel and costs to consumers of personal (unpaid) time spent on travel.

FILTERING FOR THE ACHIEVEMENT OF KEY CREDITS



KEY CREDITS	Impacts addressed		No of corresponding strategies	Resulting Envision categories
LD1.3	Community satisfaction		12 indicators	QL1.1 QL1.4 QL1.6 QL2.1 QL3.1 QL3.2 QL3.3 QL3.4
LD3.1	Economic prosperity		92 indicators	QL1.1 QL2.1 QL2.2 QL2.3 QL3.1 QL3.4 LD1.1 LD1.3 LD1.4 LD3.1 LD3.2 LD3.3 RA1.1 RA2.3 NW1.3 NW1.4 NW2.1 NW3.2 NW3.3 CR2.5 CR2.6
	Travel time value		56 indicators	QL1.3 QL1.6 QL2.1 QL2.2 QL2.3 LD2.3 LD3.1 LD3.3 RA1.2 RA1.3 RA1.4 RA1.5 RA2.2 RA3.3 NW2.4
LD3.3		Capital cost	142 indicators	QL1.3 QL1.4 QL1.5 QL2.1 QL2.2 QL2.3 QL3.3 QL3.4 LD1.2 LD2.3 LD2.4 LD3.3 RA1.1 RA1.2 RA1.4 RA1.5 RA2.1 RA2.2 RA2.3 RA2.4 RA3.2 RA3.3 RA3.4 NW1.1 NW1.3 NW2.1 NW2.2 NW2.3 NW3.1 NW3.2 NW3.4 NW3.5 CR1.2 CR1.3 CR2.5 CR2.6
		O&M cost	86 indicators	QL1.5 QL2.1 QL2.2 QL2.3 QL3.4 LD1.2 LD1.4 LD2.3 LD3.3 RA1.3 RA2.1 RA2.3 RA2.4 RA3.2 RA3.4 NW2.2 NW2.3 NW3.1 NW3.2 NW3.4 CR1.1 CR2.5 CR2.6
	agency costs	Major rehabilitation cost	58 indicators	QL1.4 QL2.1 QL2.2 QL2.3 QL3.4 LD1.2 LD2.3 LD3.3 RA1.2 NW3.1 NW3.3 CR2.5 CR2.6
		Replacement cost	64 indicators	QL1.4 QL2.1 QL2.2 QL2.3 QL3.4 LD1.2 LD2.3 LD2.4 LD3.3 RA1.2 RA2.4 NW3.1 NW3.2 NW3.3 CR2.5 CR2.6
		End-of-life cost	3 indicators	LD2.4
		Residual value	48 indicators	QL2.1 QL2.2 QL2.3 QL3.4 LD1.2 LD2.3 LD2.4 LD3.3 RA1.2 NW3.1 NW3.3 CR2.5
		Revenues	27 indicators	QL2.1 QL2.2 QL3.1 LD3.3 CR1.1 CR2.6
		Delay cost	28 indicators	QL1.1 QL1.4 QL1.6 QL2.1 QL3.2 QL3.3 LD1.3 LD3.3 NW2.4 NW3.5 NW3.1 NW3.5 CR2.5
		Liability claim cost	12 indicators	QL1.2 QL1.6 QL3.3 LD3.3
		Penalty cost	31 indicators	QL1.6 LD3.3 RA3.1 RA3.4 NW1.2 NW2.1 NW2.2 CR1.1 CR1.2 CR1.3
		Noise cost	19 indicators	QL1.4 QL1.6 LD1.4 LD2.3 LD3.3
		Restoration cost	31 indicators	QL1.3 QL1.6 QL3.3 LD3.3 RA3.1 RA3.4 NW1.3 NW2.4 NW3.1 NW3.2 NW3.5
	user costs	Travel time value	56 indicators	QL1.3 QL1.6 QL2.1 QL2.2 QL2.3 LD2.3 LD3.1 LD3.3 RA1.2 RA1.3 RA1.4 RA1.5 RA2.2 RA3.3 NW2.4
		Vehicle cost	49 indicators	QL1.3 QL1.6 QL2.1 QL2.2 QL2.3 LD2.3 LD2.4 LD2.3 RA1.2 RA1.3 RA1.4 RA1.5 RA2.2 RA3.3 NW2.4 NW3.1
		Fuel cost	48 indicators	QL1.3 QL1.6 QL2.1 QL2.2 QL2.3 LD2.3 LD2.4 LD3.3 RA1.2 RA1.3 RA1.4 RA1.5 RA2.2 RA3.3 NW2.4
		Fare cost	4 indicators	QL2.1 QL2.2 QL3.1
		Accident cost	65 indicators	QL1.2 QL1.3 QL1.5 QL1.6 QL2.1 QL2.2 QL2.3 LD2.3 LD3.3 RA1.4 RA2.1 RA2.2 NW1.4 NW2.2 NW3.1
		Health cost	104 indicators	QL1.2 QL1.3 QL1.4 QL1.5 QL1.6 QL2.1 QL2.2 QL2.3 LD1.4 LD2.3 LD3.3 RA2.1 RA3.3 RA3.4 NW2.1 NW2.2 NW2.3 NW2.4 NW3.1 NW3.2 NW3.3 NW3.4
		Job creation	22 indicators	QL2.1 QL2.2 LD3.2 LD3.3 NW1.4 NW2.1
		Economic prosperity	92 indicators	QL1.1 QL2.1 QL2.2 QL2.3 QL3.1 QL3.4 LD1.1 LD1.3 LD1.4 LD3.1 LD3.2 LD3.3 RA1.1 RA2.3 NW1.3 NW1.4 NW2.1 NW3.2 NW3.3 CR2.5 CR2.6
CR1.1	Embodied carbon		85 indicators	QL1.3 QL1.4 QL1.5 QL1.6 QL2.1 QL2.2 QL2.3 QL3.4 LD1.2 LD1.4 LD2.3 LD2.4 RA1.1 RA1.2 RA1.3 RA1.4 RA1.5 RA2.2 RA2.3 RA2.4 RA3.3 NW1.4 NW2.3 NW3.1 NW3.3 NW3.4 NW3.5 CR2.5 CR2.6
CR1.2	Emissions		94 indicators	QL1.3 QL1.4 QL1.5 QL1.6 QL2.1 QL2.2 QL2.3 LD1.2 LD1.4 LD2.3 LD2.4 RA1.4 RA1.5 RA2.1 RA2.2 RA2.3 RA2.4 RA3.3 NW2.4 NW3.3 CR2.6
CR2.5	Resilience value (agency)		108 indicators	QL2.1 QL2.2 QL2.3 LD1.2 LD1.4 LD2.3 LD2.4 LD3.1 LD3.2 LD3.3 RA2.1 RA2.3 RA3.1 RA3.2 RA3.4 NW2.2 NW2.3 NW3.1 NW3.2 NW3.3 NW3.4 CR1.3 CR2.5 CR2.6
	Resilience value (user)		88 indicators	QL2.1 QL2.2 QL2.3 LD1.2 LD2.3 LD2.4 LD3.1 LD3.2 LD3.3 RA2.3 RA3.1 RA3.2 NW2.2 NW2.3 NW3.2 NW3.4 CR1.1 CR1.2 CR2.5 CR2.6

- The impacts of key credits provide the basis for this filtering
- The filtering result indicates which strategies should be applied to achieve Key credits.
- The strategies are described in detail in the background table

The Lifecycle Sustainability Tool can be used as:

Lifecycle assessment tool:
Combined with the Envision framework tools, the tool can assist users to identify and understand their project's TBL impacts, as well as evaluate its performance in each lifecycle stage.

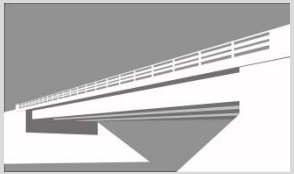
Multiple criteria, decision-making tool:
Provides an informed framework for comparative analysis between different alternatives whose impacts and benefits can be directly assessed and addressed.

Evidence-based documentation of project decisions:
The tool can assist infrastructure owners to support their decisions with evidence of TBL and whole life impacts or efficiently document experience-based strategies.

Guidelines to enhance sustainable performance:
Sustainability indicators serve as guidelines to **enhance the project's sustainable performance**. In the early stages of planning and design development, the indicators could function as targets to pursue.

Educational manual for lifecycle sustainability:
Providing information regarding the impacts of each sustainability strategy along the lifecycle it educates on best-performing strategies in the long-term.

PILOT APPLICATION OF THE TOOL



PILOT APPLICATION OF THE TOOL ON A BRIDGE REPLACEMENT PROJECT

The **Sustainability Lifecycle Tool** was pilot used on a transportation project **to demonstrate** how:

- it can assist project teams **with evidence and documentation of their decisions on strategies and specifically evidence of how these strategies address TBL sustainability and lifecycle** performance.
- to test if an agency's **areas of priority and concern** are adequately captured.

A small-scale **typical bridge replacement project** by the Ministry of Transportation of Ontario (MTO) West Region was used as a case study to provide input for the research.

PROJECT OVERVIEW

Project Name:	Bayfield River Bridge Replacement Project
Project Type:	Two-lane Rural highway Bridge Replacement
Location:	Ontario, Canada
Owner :	MTO's West Region
Project Team:	McIntosh Perry
Project Lifespan:	75 years
Year of construction	2019
Current Status:	Operating

The project incorporated a mix of both **agency-wide established strategies** as well as **innovative approaches** that have been pilot-tested and proven successful, such as:

- Use of integral abutments with joint-less details, a zero-maintenance solution
- Use of accelerated bridge construction (ABC) to reduce construction duration, minimize public disruption, and avoid project construction carry-over beyond one construction season.

PROJECT OVERVIEW

	Existing 87yr-old bridge	New bridge with 75 yr-service life
Span	two-span	Single-span
Overall structure width	11.53 m	14.96 m
Length	32.5 m	40.0 m
Roadway width	9.402 m	
Width of lane	3.65 m	3.75 m
Width of shoulder	1.3 -3.0	2.0- 2.5 m
Sidewalk width	1.2 m	2.0 m
Superstructure Type	Cast-in-place concrete tee-beam structure	Composite Steel Box Girder
Substructure Type	Cast-in-place concrete abutments and concrete pier, both founded on spread footings	Precast integral abutments on steel H-piles and precast cantilevered wing walls

PROJECT OVERVIEW

Use of Duplex 2205 grade stainless steel in the entire deck and approach slabs

Transport of the supermodule from the temporary yard to the site with multi-axle hydraulic trailers with spacers

Uplift of the supermodule with heavy lift crane (each component weighed approximately 90-95 tonnes and was 40.6 m long)

Erection of supermodule to its final position

PROJECT CORE SUSTAINABLE STRATEGIES

The project's **core strategies identified** through the Envision Checklist:

top multi-benefit strategies

CORE STRATEGIES
Bridge replacement vs. rehabilitation
Single-span vs. original two-span
Use of Integral abutment with joint-less details
Redundant corrosion protection system (use of premium materials)
Construction quality
Salvage of old structure parts
ABC construction
Use of prefabricated components
Performance of selected works off-site during a seasonal shutdown
Staged construction
Correction of horizontal alignment
Correction of vertical alignment & embankment widening
Widening of the highway section
Increased sidewalk width
Extension of the sidewalk beyond project limit
Provision for a future bicycle lane
Use of ready-mix plant near worksite (15 min)

Top multi-benefit strategies:

- They are strategies that emerged during discussion with the representatives of the MTO's West Region**.**
- They secure optimized durability, minimize future maintenance needs and minimization of community disruption.
- **They enable cost offsetting through a balance of downsizing of structures, less materials and schedule efficiency.**

PROJECT CORE STRATEGIES & ENVISION CREDITS ADDRESSED

top multi-benefit strategies

CORE STRATEGIES	RELATED ENVISION CREDITS									
Bridge replacement vs. rehabilitation	QL1.2	QL1.4	QL2.1	LD2.3	LD2.4	LD3.1	LD3.3	CR1.1	CR1.2	CR2.5
Single-span vs. original two-span	NW1.2	NW3.1	NW3.2	NW3.3	LD2.3	LD3.3	CR1.1	CR2.2	CR2.3	
Use of Integral abutment with joint-less details	QL1.6	LD2.3	LD2.4	LD3.3	CR1.1	CR1.2	CR2.2	CR2.3	CR2.4	CR2.5
Redundant corrosion protection system (use of premium materials)	LD2.3	LD2.4	LD3.3	CR1.1	CR2.3	CR2.5				
Construction quality	LD2.3	LD2.4	LD3.3	CR1.1	CR1.2	CR2.5				
Salvage of old structure parts	RA1.2	RA1.4	CR1.1							
ABC construction	QL1.2	QL1.6	LD3.1	LD3.2	LD3.3	RA2.2				
Use of prefabricated components	QL1.3	QL1.6	LD2.3	LD2.4	LD3.2	RA2.2				
Performance of selected works off-site during a seasonal shutdown	QL1.3	QL1.6	LD2.3	LD3.3						
Staged construction	QL1.3	QL1.6	LD3.1	LD3.3						
Correction of horizontal alignment	QL1.2	CR2.6								
Correction of vertical alignment & embankment widening	QL1.2	NW3.3	CR2.2	CR2.3	CR2.4	CR2.5	CR2.6			
Widening of the highway section	QL1.2	QL2.1	LD2.3	LD3.1						
Increased sidewalk width	QL1.2	QL2.1	QL2.3	LD1.3						
Extension of the sidewalk beyond project limit	QL1.2	QL2.3	LD3.1							
Provision for a future bicycle lane	QL2.1	QL2.2	QL2.3	CR2.6						
Staged construction	QL1.3	QL1.6	LD3.1	LD3.3						
Use of ready-mix plant near worksite (15 min)	RA2.2	CR1.1								

The table indicates how one strategy can address multiple credits, as well as how multiple strategies address one credit.

The project team made **significant efforts** to extend the useful life of the project in order to **minimize the need for maintenance works**.

These efforts are evident in the following core sustainable strategies they implemented in the project:

PROJECT'S CORE STRATEGIES RELATED TO REDUCTION OF FUTURE MAINTENANCE WORKS	RELATED ENVISION CREDITS									
Bridge replacement vs. rehabilitation	QL1.2	QL1.4	QL2.1	LD2.3	LD2.4	LD3.1	LD3.3	CR1.1	CR1.2	CR2.5
Single-span vs. original two-span	NW1.2	NW3.1	NW3.2	NW3.3	LD2.3	LD3.3	CR1.1	CR2.2	CR2.3	
Use of Integral abutment with joint-less details	QL1.6	LD2.3	LD2.4	LD3.3	CR1.1	CR1.2	CR2.2	CR2.3	CR2.4	CR2.5
Redundant corrosion protection system (use of premium materials)	LD2.3	LD2.4	LD3.3	CR1.1	CR2.3	CR2.5				

However, during the analysis of the project it was observed that the **Envision Checklist does not fully capture** the impacts related to minimization of **future maintenance works, a key area of concern for transportation projects**.

ENVISION®

- Envision includes numerous Credits that **assess the impacts related to construction works** (during the construction stage).

- However, **the impacts of reducing maintenance works**, (i.e. future construction works during the maintenance phase) are assessed only by two credits:

  LD2.3 Plan for Long-Term Monitoring and Maintenance

  CR2.5 Maximize Resilience

  These credits award how the project is designed and managed for an extended service life, and thus **avoids frequent future construction works** and their associated impacts**.**

Aiming towards a comprehensive assessment towards all LC stages, the LC Sustainability tool **suggests that the impacts of the reduction of maintenance works should be assessed** when documenting related credits.

How does the tool address and identify these impacts?

The LC Sustainability tool suggests a similar approach for the maintenance LC stage as with (initial) construction LC stage, that assesses as TBL impacts:

impacts of construction works

SOCIAL	ENVIRONMENTAL
Access	Materials
Safety	Energy
Health	Water
Noise	Water quality
Light pollution	Embodied water
	Air quality
	Waste
	Soil quality
	Emissions
	Ecosystem quality
	Land occupation

* Embodied carbon and costs of future maintenance are accounted by the relevant credits

To highlight the importance of decisions on strategies that minimize maintenance **needs, the tool breaks down all positive impacts that derive from the avoidance of future construction works**

Impacts of future construction works

DIRECT IMPACT	INDIRECT TBL IMPACT
Access	travel time value vehicle cost fuel cost Energy (fuel user) Emissions (user) climate change
Safety	health health cost Accident cost
Noise	noise cost wellbeing Health ecosystem quality
Light pollution	safety energy emissions accident cost ecosystem quality

DIRECT IMPACT	INDIRECT IMPACT
materials	(+) embodied energy (+) embodied water (+) embodied carbon (+) climate change (+) resource depletion
energy	(+) emissions (+) climate change
waste	(+) embodied energy (+) embodied water (+) embodied carbon (+) land occupation (+) water quality
water	(+) resource depletion
water quality	(+) resource depletion (+) ecological quality
air quality	(+) health
ecosystem quality	(+) ecological resilience
land occupation	(+) ecological quality
soil quality	(+) water quality (+) ecological quality

The tool, thus, incorporates **future construction works'** impacts to all relevant credits:

- QL1.4 Minimize Noise & Vibration
- QL2.1 Improve Community Mobility
- QL2.2 Encourage Sustainable Transportation
- QL2.3 Improve Access & Wayfinding
- QL3.4 Enhance Public Space & Amenities
- LD1.2 Foster Collaboration and Teamwork
- LD2.3 Plan for Long-Term Monitoring & Maintenance
- LD2.4 Plan for end-of-life
- RA1.2 Use Recycled Materials
- NW3.3 Maintain Floodplain Functions
- CR2.5 Maximize Resilience
- CR2.6 Improve Infrastructure Integration

ACCOUNTING FOR THE TBL IMPACTS OF FUTURE CONSTRUCTION WORKS

ENVISION CREDITS

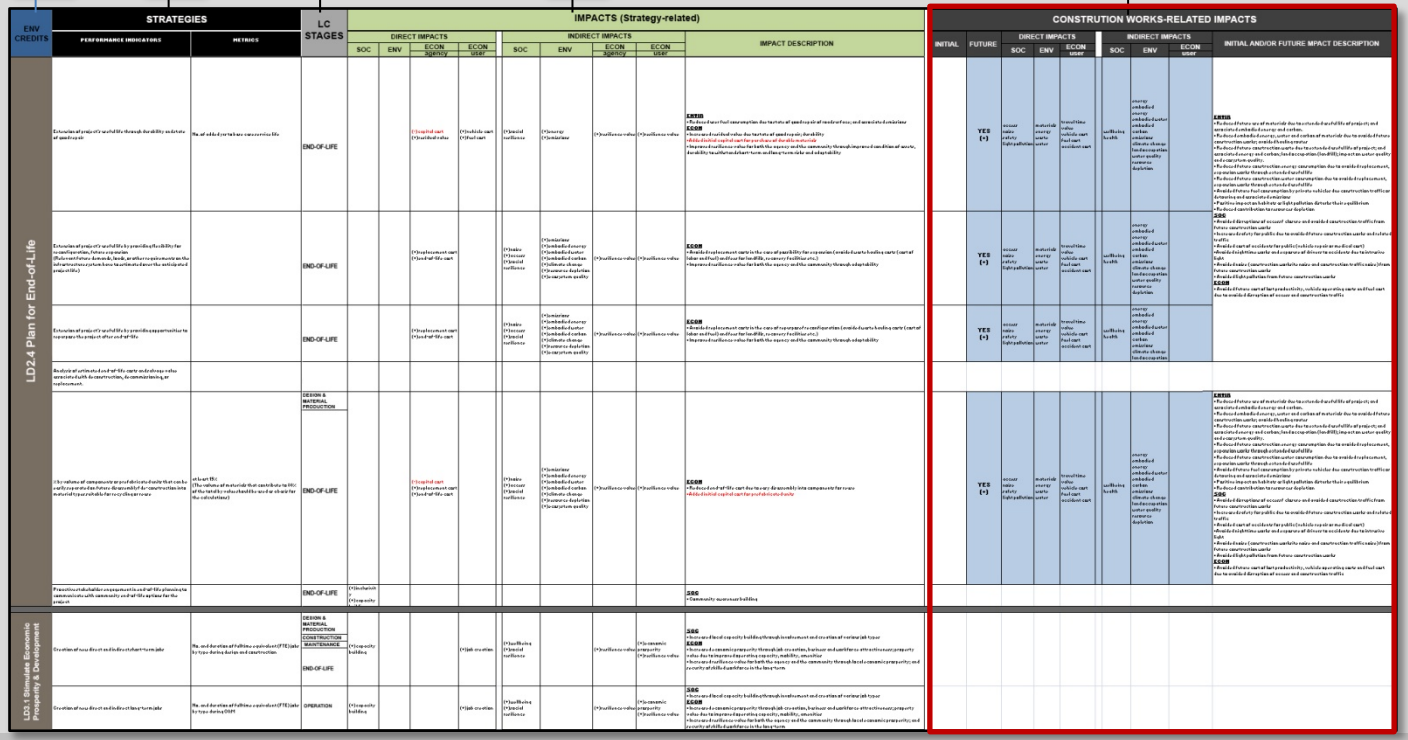
STRATEGIES

LC STAGE

TBL IMPACTS

CONSTRUCTION WORKS -RELATED TBL IMPACTS

ADDITION TO BACKGROUND EXCEL TABLE

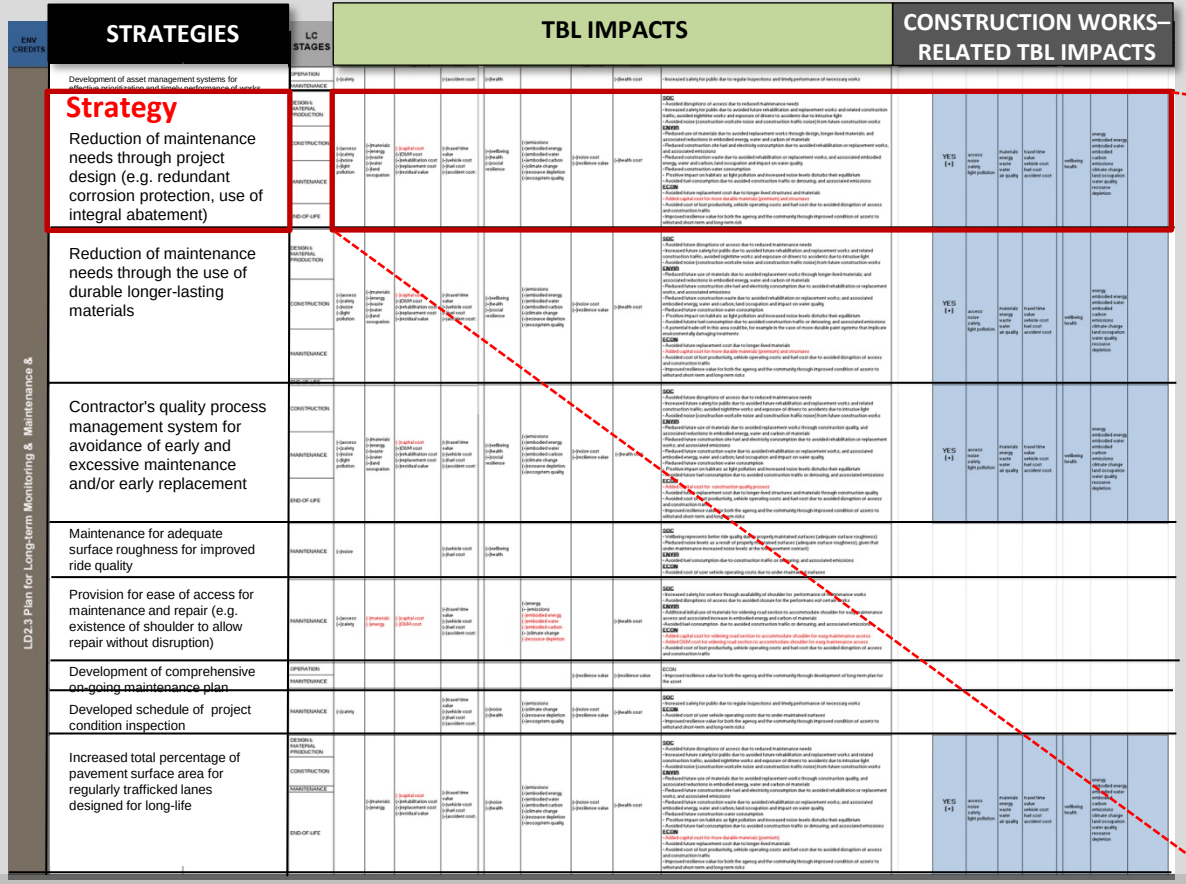


construction works-related TBL impacts are distinguished in:

- **Initial** (during construction phase)
- **Future** (during maintenance phase)

EXAMPLE OF A STRATEGY WITH FUTURE IMPACTS

CREDIT LD2.3
Plan for Long-term Monitoring & Maintenance



Strategy: Reduction of maintenance needs through project design (e.g. redundant corrosion protection, use of integral abatement)

Strategy's TBL Impacts

EXAMPLE OF A STRATEGY WITH FUTURE IMPACTS

Strategy: Reduction of maintenance needs through project design (e.g. redundant corrosion protection, use of integral abatement)

CREDIT LD2.3
Plan for Long-term Monitoring & Maintenance

Environmental impacts

DIRECT IMPACT	INDIRECT IMPACT	IMPACT DESCRIPTION	INITIAL	FUTURE
(+) materials	(+) embodied energy (+) embodied water (+) embodied carbon (+) climate change (+) resource depletion	Reduced material use due to optimizing the size of structures due to the redundant corrosion system/ premium materials	Short-term	
		Reduced use of materials (permanent) due to avoided replacement works through design, longer-lived materials		Recurring short-term
		Reduced use of temporary material for replacement works (equipment, safety barriers/ temporary signage, noise barriers, etc.)		Recurring short-term
		Reduced embodied energy, water, and carbon of materials due to avoided maintenance needs; avoided hauling routes		Recurring short-term
(+) energy	(+) emissions (+) climate change	Avoided future construction worksite energy consumption and associated emissions		Recurring short-term
(+) waste	(+) embodied energy (+) embodied water (+) embodied carbon (+) land occupation (+) water quality	Reduced construction waste due to avoided rehabilitation or replacement works		Recurring short-term
		Reduced future embodied energy, water, and carbon of construction waste Reduced land occupation for landfilling Improved water quality		
(+) water	(+) resource depletion	Avoided future construction water consumption Reduced contribution to depletion of resources		Recurring short-term
(+) water quality	(+) resource depletion (+) ecological quality	Increased water quality due to avoided incidents of debris into water course through avoided in-water works and avoided costs of remediation and schedule delays		Long-term
(+) air quality	(+) health	Avoided future emissions of air pollutant emissions, e.g. volatile organic compounds (VOC) by construction site equipment		Recurring short-term
		Avoided potential health impact from exposure to air pollutant emissions		Recurring short-term
(+) ecosystem quality	(+) ecological resilience	Avoided incidents of environmental incidents during construction works to adjacent habitats and of potential costs for remediation		Long-term
(+) land occupation	(+) ecological quality	Reduced undeveloped land occupation (for temporary works) and of potential costs for remediation		Recurring short-term
(+) soil quality	(+) water quality (+) ecological quality	Avoided impacts to soil health and preservation of related ecosystem services provision Avoided potential costs for remediation and schedule delays		Long-term

Future construction work-related impact

The table indicates that the strategy generates positive (+) environmental future impacts

EXAMPLE OF A STRATEGY WITH FUTURE IMPACTS

Strategy: Reduction of maintenance needs through project design (e.g. redundant corrosion protection, use of integral abatement)

CREDIT LD2.3
Plan for Long-term Monitoring & Maintenance

Social impacts

DIRECT IMPACT	INDIRECT IMPACT	IMPACT DESCRIPTION	INITIAL	FUTURE
(+) access	(+) travel time value (+) vehicle cost (+) fuel cost (+) energy (+) emissions (+) climate change	Avoided disruptions of access/ closure due to reduced maintenance needs; avoided construction traffic; and due to properly maintained surfaces (adequate surface roughness)		Recurring for the period of works & Long-term (due to state of good repair, adequate surface roughness)
		Avoided fuel consumption by private vehicles due to construction traffic or detouring and associated emissions		
		Avoided cost of lost productivity, vehicle operating costs, and fuel costs due to avoided disruption of access and construction traffic; and due to properly maintained surfaces (adequate surface roughness)		
(+) safety	(+) health (+) health cost	Increased safety due to durable structures		Long-term
	(+) accident cost	Increased safety due to avoided future construction works and related traffic Avoided cost of accidents for public (vehicle repair or medical cost)		Recurring short-term
(+) noise	(+) noise cost (+) wellbeing (+) health (+) ecosystem quality	Avoided future construction worksite noise for future maintenance; construction traffic noise		Recurring for the period of works
		Avoided operational noise/ vibration due to state of good repair	Long-term	Long-term
		Avoided cost for passive noise mitigation (e.g.) Sound Insulation schemes for affected residences	Long-term	Long-term
		Avoided potential health impact from increased noise levels Positive impact on habitats as increased noise levels disturb their equilibrium		Long-term
(+) light pollution	(+) safety (+) energy (+) emissions (+) accident cost (+) ecosystem quality	Avoided energy consumption due to light wastage during nighttime works and associated emissions Positive impact on habitats as light pollution disturbs their equilibrium Avoided nighttime works and exposure of drivers to accidents due to intrusive light		Recurring for the period of works

Future construction work-related impact

The table indicates that the strategy generates positive (+) social future impacts

EXAMPLE OF A STRATEGY WITH FUTURE IMPACTS

Strategy: Reduction of maintenance needs through project design (e.g. redundant corrosion protection, use of integral abatement)

CREDIT LD2.3
Plan for Long-term Monitoring & Maintenance

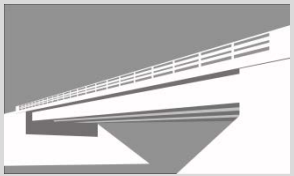
Economic impacts

DIRECT IMPACT	INDIRECT IMPACT	IMPACT DESCRIPTION	INITIAL	FUTURE
(-) capital cost		Added capital cost for more durable materials (premium) and structures	Short-term	
		Reduced capital cost for labor or transport of heavier components (for downsized structures)	Short-term	
(+) rehabilitation cost		Avoided future rehabilitation cost due to longer-lived structures and materials		Recurring short-term
(+) replacement cost		Avoided future replacement cost due to longer-lived structures and materials		Recurring short-term
(+) residual value		Increased residual value		future

Future construction work-related impact

The table indicates that the strategy's added initial capital cost (for premium materials) is offset (partially or entirely*) by positive (+) economic future impacts

* The net cost balance is yet to be quantified. The LC Sustainability tool doesnot provide with net balances neither for cost or other impacts. The tool identifies and maps impacts and it is up to the project team to further quantify or monetize impacts.



The Lifecycle Sustainability tool provides evidence-based documentation of the Bayfield Bridge replacement project decisions:

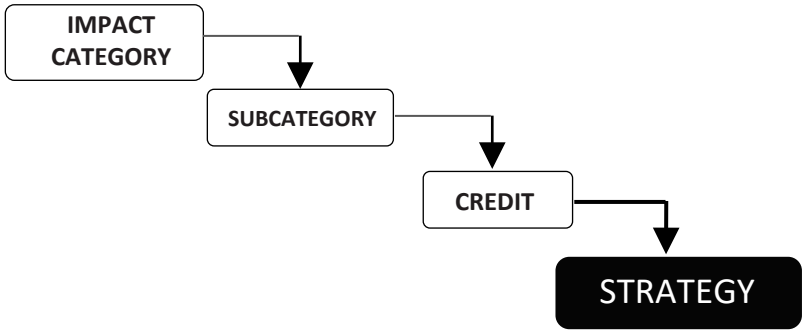
The tool assists the MTO's West Region to support and document their decisions with evidence of TBL and whole life impacts of the strategies that were incorporated in the project (both innovative and experience-based strategies).

It specifically address key areas of concern for transportation projects, such as the TBL impacts of the Maintenance LC stage

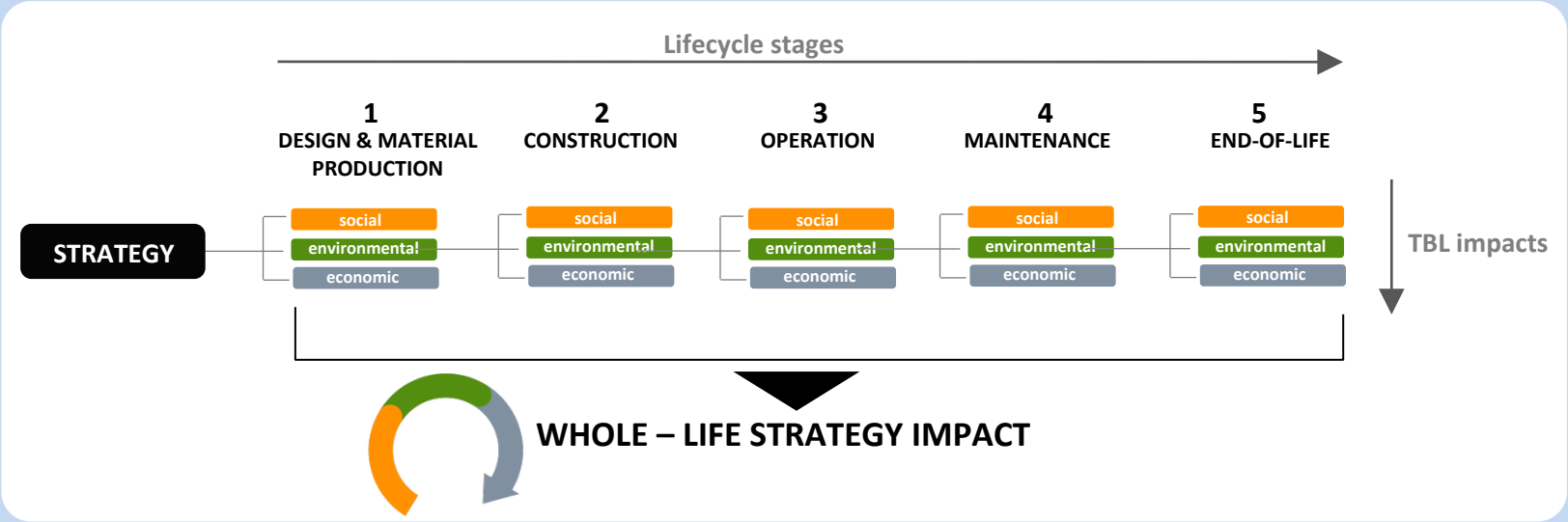
ADD-ONS TO THE ENVISION MANUAL

1 **Creation of list of strategies per Envision credit. A new structural unit was added to the Envision structure:** the **strategies** towards achieving each credit

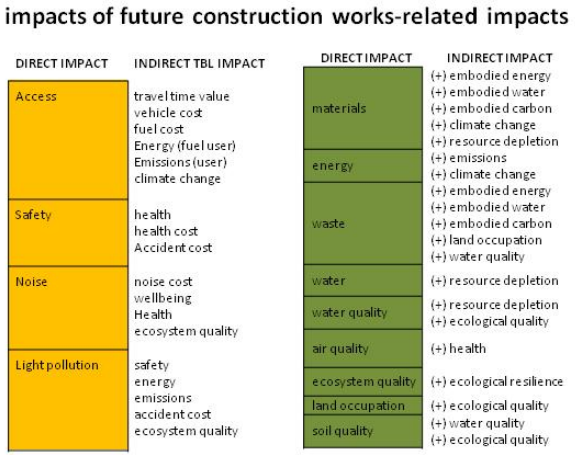
ENVISION STRUCTURE



2 Each credit strategy is linked to its direct & indirect TBL impacts for all lifecycle stages



3 Addition of a lifecycle dimension to impacts, as in the case of the impacts of future maintenance works



Strategies were linked with 'future construction works' impact where relevant.

This impact contains all social and environmental impacts that result from construction works as in the case of future rehabilitation or replacement needs that were not fully captured by Maintenance stage-related Envision credits

4 **The identification of key credits** as credits that request input from other Envision credits

KEY CREDITS	CORE IMPACTS ADDRESSED	
	TBL IMPACT FOR FILTERING	TBL CATEGORY
LD1.3 Provide For Stakeholder Engagement	COMMUNITY SATISFACTION	SOCIAL
LD3.1 Stimulate Economic Prosperity	ECONOMIC PROSPERITY	ECONOMIC
	TRAVEL TIME VALUE	ECONOMIC
LD3.3 Conduct A Lifecycle Economic Evaluation	ALL ECONOMIC IMPACTS	ECONOMIC
CR1.1 Reduce net embodied carbon	EMBODIED CARBON	ENVIRONMENTAL
CR2.2 Reduce GHG Emissions	EMISSIONS	ENVIRONMENTAL
CR2.5 Maximize Resilience	RESILIENCE VALUE	ECONOMIC

5 Enhancement of the economic dimension of Envision by linking economic impacts to each credit's strategies where relevant

ECONOMIC IMPACTS

AGENCY	USER
Capital (initial)cost	Travel time value
O&M cost	Vehicle cost
Rehabilitation cost	Fuel cost
Replacement cost	Fare cost
Residual value	Accident cost
Revenues	Health cost
Delay cost	Job creation
Liability claim / Penalty cost	Economic prosperity
Noise cost	Resilience value
Restoration cost	Ecosystem services value
Resilience value	
Ecosystem services value	

The added economic impacts include:

- Costs/benefits for both the agency/owner and the user
- initial and future costs

And aim to reflect the promoted by Envision shift of focus from monetary to total value

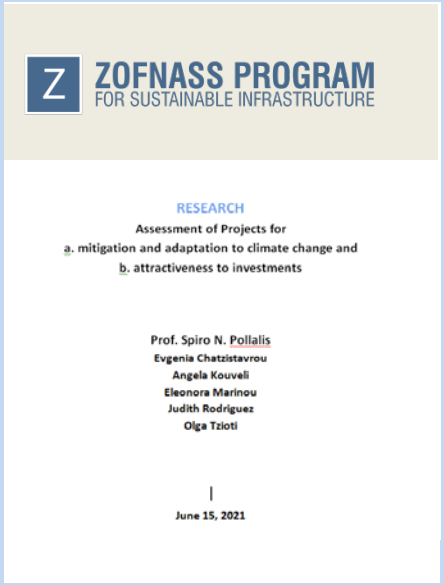
NEXT STEPS

THE SUSTAINABILITY LC TOOL AS A DYNAMIC FRAMEWORK

The LC Sustainability tool is a dynamic and flexible framework.

The list of strategies and impacts can be expanded to incorporate e.g. innovative strategies as they emerge from active areas of research, or incorporate additional level of detail according to needs.

For example, as part of the 2020-21 ZHP research on climate change:


ZOFNASS PROGRAM
FOR SUSTAINABLE INFRASTRUCTURE

RESEARCH

Assessment of Projects for
a. mitigation and adaptation to climate change and
b. attractiveness to investments

Prof. Spiro N. Pollalis
Evgenia Chatzistavrou
Angela Kouveli
Eleonora Marinou
Judith Rodriguez
Olga Tzioti

June 15, 2021

- **The impact 'emissions' was further disaggregated into:**
  - Scope 1 emissions
  - Scope 2 emissions
  - Scope 3 emissions

  For clarification of the GHG emissions involved in each strategy

- A climate-related risk was added and linked to the impact 'emissions', the '**transition risk'**, as defined by TCFD to highlight less or more exposure to related potential financial impacts (e.g. reputation-related, technology-related, lock-in technology related, change in demand-related).

- **The definition of the impact 'resilience value**' was enhanced, based on TCFD climate-related financial risks & opportunities, and categorized as:
  - Physical asset risk
  - Service continuity risk
  - Resource availability risk (water, materials, land, workforce)
  - Supply chain continuity risk

The development of the tool **highlighted the significance of key credits** and revealed a trend of project teams to not pursuing their achievement.

Especially in the case of credits:

LD3.3 Conduct A Lifecycle Economic Evaluation
CR1.1 Reduce net embodied carbon
CR2.2 Reduce GHG Emissions

In most cases no achievement in these KEY CREDITS is due to not having developed LCAs.

What the tool offers

- By linking strategies to detailed economic costs, and impacts like 'embodied carbon' and 'GHG emissions' the tool can assist project teams **to identify and list all their project strategies related to these impacts**.
- **A supplemental guide designated for these credits achievement** can be developed through targeted filtering of impacts to complement Envision. Project teams will be provided with a predefined list to build upon and **further quantify and monetize these impacts**.

THANK YOU